The Engineering Review.

Edited by

C. EDGAR ALLEN, A.M.I.E.E., Etc.

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THE NATIONALISATION OF RAILWAYS.

THE question of the nationalisation of railways is not a new one; it regularly recurs as a consequence of some incident which forcibly brings home to shareholders and the public alike the enormous expense and waste attaching to the present competitive system. While State ownership has become an established fact on the Continent, South America, Australia, and New Zealand, the question has not yet reached a prominent position in the practical politics of this country, and neither of the two great parties have, at present, included it within their programmes. Recent events, however, have tended to bring the matter to the forefront, important among which are the advent of the Labour and Socialist parties in the House of Commons; agitations on the part of railway employés for better pay and conditions of labour; and the powerful movement of a section of shareholders of one of our leading lines with a view of securing reformed methods of working. The question has also been presented for discussion to the Association of Chambers of Commerce of the United Kingdom, and, finally, the working arrangements concluded between the Great Northern and Great Central Railways, and within the past few weeks of the London and North Western and Midland Companies, have played an important part in bringing the whole working and administration of the railways up for consideration.

At this juncture, therefore, it may be well to draw attention to an admirable and lucid exposition of the subject by A. Emil Davies, whose little book* deserves the earnest attention of all interested to the smallest degree in railway matters.

The principal indictment made by him against the railway companies is waste—waste of the grossest description, and in putting his case, he considers such items as superfluous directors and useless officials; duplication of services; waste in working; small truck loads and duplicate stations.

Most of these defects—inherent in the competitive system—are overlooked by many who insist on the benefits which can only be derived from the absence of monopoly. Their real existence has, however, been demonstrated of late by the difficulty found in maintaining dividends, and a remedy has been sought

* "The Nationalisation of Railways." London: Adam and Chas. Black, 1908.

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in the working arrangements recently concluded. To what extent these reforms will facilitate traffic or benefit the public, apart from securing the main object, which, of course, relates to increased profits, remains to be seen; but granted the success of the experiment from the shareholders' point of view, it is only under State administration that the interests of the country as a whole would be considered and the reduction and uniformity of goods rates and passenger fares secured.

Mr. Davies' arguments and facts in support of the last statement are potent and convincing, which, however, cannot be said for his presentation of the case against nationalisation. This is possibly because he relies upon Lord Avebury for his refutation of State management, who endeavours to prove that British railways are in every respect superior to Continental systems. The latter, however, as is shown by Mr. Davies, present wider differences than do those of England and France, and Lord Avebury carefully refrains from pointing out that, what are probably the worst railway systems in the whole world, namely, those of Spain and Portugal, are run entirely by private companies.

The principal objections that can be, and are generally, urged against nationalisation are that the management will be inefficient, bound up with red tape, and give rise to political corruption. Mr. Davies, however, cites the postal service, the management of our dockyards, the work of the Civil Service generally, in India, at home and in the Colonies, all of which are marked by the highest degree of efficiency, as sufficient refutation of such objections.

The most striking testimony in favour of nationalisation of the railways is that, with the exception of Great Britain, the United States, Canada, Spain and Portugal, every civilised country has adopted and is extending the principle of State ownership, and it is only by appealing to prejudices foreign to the question instead of judging its expediency on its merits that its progress has been hindered in this country.

The following extract from an article by Prof. Cohn * shows the results of railway nationalisation in Prussia:—

> These railways were acquired by the Prussian Government in 1880 at a price which left the shareholders a considerable margin of profit.
>
> Since the year 1882 the revenue earned by the Prussian State Railway has not only sufficed to pay the interest on the capital and wipe out the debt, but, over and above this, has yielded a surplus which has remained at the disposal of the Government for other national expenses. The figure of this annual surplus has steadily increased from £1,000,000 in the years 1882–1887 to £23,000,000 in 1905, and in the budget of 1907 it is estimated at £30,000,000. This amounts to very little less than three times the yield of the Prussian income tax, or more than double the income and property taxes taken together (£13,000,000). Yet these two are still the cardinal points of the Prussian fiscal policy, and so long as the railway surplus played no very important part, *i.e.*, until 1887, financiers were completely dependent on their productivity. The situation has been changed since 1890, when the railways began to contribute sums of from four to five millions to the national exchequer. Since then the figures have rapidly increased (in 1897 the surplus was 10 millions), so that the grand total for the years 1882—1907 amounts to about £260,000,000.

Although the problem presents itself in different guises in the various countries, a consideration of the above cannot fail to impress upon one the

* *Economic Journal* Jan., 1908.

benefit to the national exchequer accruing from a centralised management. This, however, is not the only thing that would be secured under State control, and it will suffice to again instance Germany—to say nothing of Belgium and other countries—who, in providing special rates for export traffic, considers not merely the ends of the railway administration alone but the interests of the country as a whole.

Such a state of affairs appears to be quite out of the question with privately owned lines, the facts showing that, so far from our own export trade receiving any benefit, the exact opposite is the case.

There is little to urge why reasonably high speeds and the present standard of comfort should not be maintained under national ownership; but assuming that any valid objections could be found, we have the Compagnie Internationale des Wagons-Lits—whose services in Europe leave nothing to be desired—providing an instance of privately-owned trains running over State-owned lines.

Those who are in doubt as to how the money is to be found for purchasing the railways may find their perplexity alleviated by a perusal of Mr. Davies' book, which we cordially recommend as an intelligent and unbiassed exposition of the subject. Readers interested may be surprised to learn that a Railway Nationalisation Society has now been formed, the address of which is 5, Duke Street, Adelphi, W.C.

ELECTRIC PROPULSION OF STEAMSHIPS.

The electro-mechanical propulsion of steamships is a subject to which few have given the attention it perhaps deserves. The number of small boats fitted with an electrical drive is steadily increasing, and the idea has found favour with some that its application might be extended with advantage to vessels of larger tonnage. The latest advocate of the system is Mr. W. P. Durtnall, whose paper, presented before the Institute of Marine Engineers, will be found summarised on another page. The author perhaps did not take that care in the selection of his figures that he should have done, nevertheless the proposals put forward by him are not diminished in importance and should give rise to an interesting discussion at the next meeting. Briefly, Mr. Durtnall's claim is, that by using turbo-generators, driving electric motors coupled to the propeller shafts, both turbines and propellers could be run at their most efficient speeds with a saving of 40 per cent. in coal consumption at full speed and 37 per cent. at half-vessel speed. He further claims that the total cost of the plant will not exceed that required under the present system, as smaller turbines could be fitted, no reversing turbines would be required, and consequently less boiler and condenser capacity. We shall return to the subject after the discussion has been held.

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Steel Bands for Power Transmission.

By Dr. ALFRED GRADENWITZ.

Various are the materials which, by their frictional resistance to slipping, are suitable for the construction of belts. Leather, vulcanised india-rubber, waterproofed cotton, llama hair, and catgut are in use; the application of a steel band as described by the author, however, constitutes a novelty. (Ed. *E.R.*)

ENDEAVOURS have frequently been made to replace leather belts, ropes and chains, as used in the transmission of power, by some material of greater strength, and the use of steel bands has been suggested in this connection. Until a short time ago this problem was, however, generally considered as one which could not be successfully solved; in fact, there were most serious difficulties to be overcome, and many years of careful investigation were required before a practical solution could be found.

The steel belts recently designed for power transmission by a German Government engineer, Herr Eloesser, are based upon a strictly scientific theory of metal bands. They are being rapidly introduced in Germany and are giving excellent results in many of the largest factories and power stations.

The most important feature of these steel belts, and which practically accounts for their success, is the splice used to join their ends. This splice or lock (Fig. 1) comprises a central stationary part and two lateral flanges attached to the upper portion of the lock, the two belt ends being secured between the upper and lower portions of the lock. These portions, when the belt is ready to be installed, are fitted into one another by a locking device and screwed together, in addition to which they are soldered with a special solder of low melting point. The flanges of the lock constitute flexible joints, ensuring a ready passage of the rigid parts over the pulleys. Various types of splice are used, each of which is designed for a given minimum pulley diameter.

Another essential point of the invention is the special friction coating with which the pulley is covered. This coating consists of sheets of canvas to which are glued fine sheets of cork, and gives with steel belts a better gripping action than that which exists between leather belts and iron pulleys. While special friction coatings would hardly be found suitable in the case of leather belts, the more so as they would be subject to rapid wear and tear, they give excellent results in the case of steel bands, the slipping of which is exceedingly low, viz. about ·1 per cent., thus reducing the wear of the coating to a minimum.

LOCKING DEVICE FOR FASTENING STEEL BELTING.

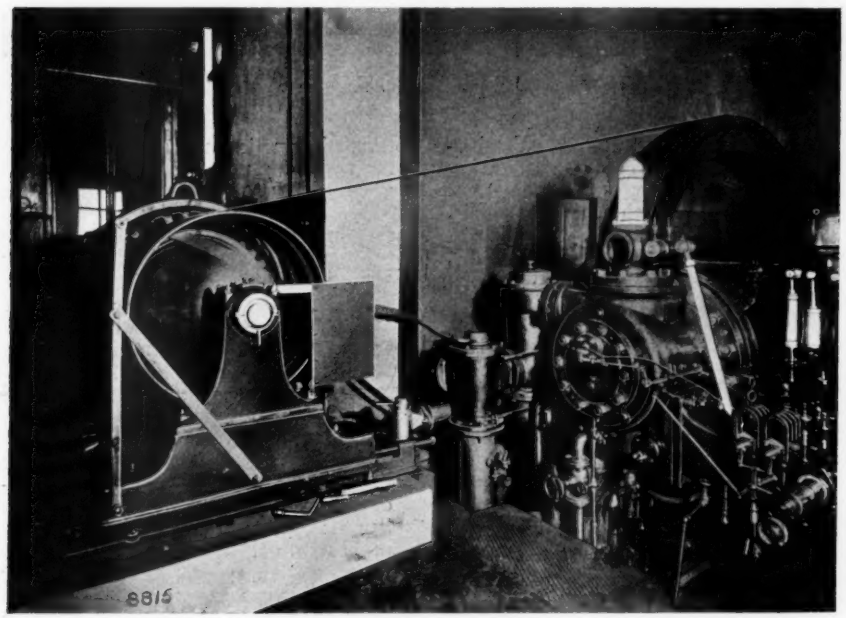
Another point of importance was the provision of means by which the steel band, on being applied, might have imparted to it a proper tension. It should be noted that, while large-size belts are applied by drawing together their two ends with a special tightening device, in order to be then joined, the steel bands are locked before being fixed on the pulleys. This manipulation,

owing to the relatively small width of the band is comparatively simple, even in the case of large powers. In order to then ascertain the proper length of band ensuring to the latter the most suitable tension, a special measuring process has been devised. A narrow steel band, one square millimeter in cross-section, is first applied to the pulleys previously to the power belt, the ends being brought together, while the power effect is ascertained. After proper adjustment of the latter, the ends of the band are cut so as to exactly touch one another, and this measuring band is used as a model in preparing the power belt. The latter accordingly, after being slipped over the pulleys, shows the same specific tension as that ascertained with the measuring band.

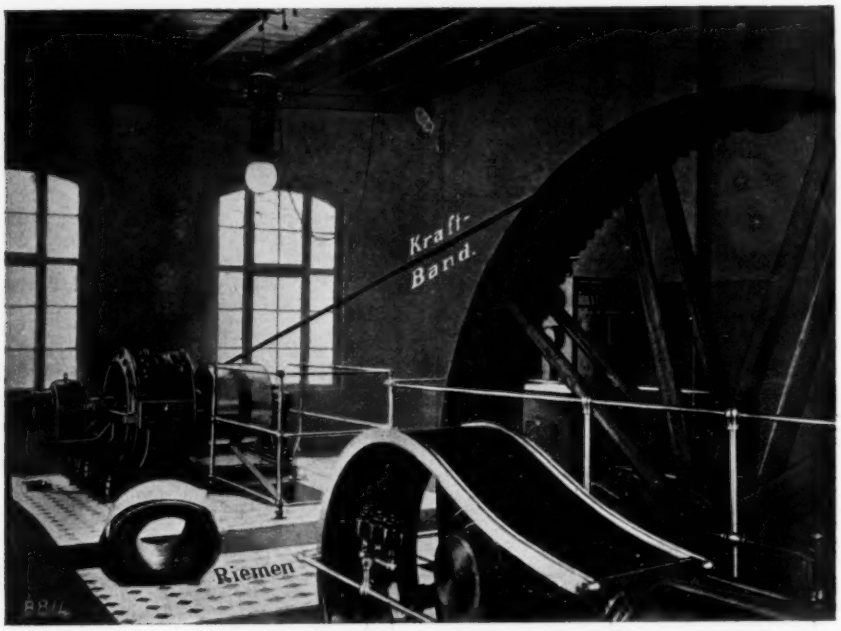
ADVANTAGES.

As regards the advantages afforded by these belts over the ordinary means of power transmission, the considerable reduction in the width of the belt is the most striking. In fact, a belt about one-fifth as wide as a leather belt of equivalent strength will in the case of large-size plants be found quite satisfactory.

One of the first installations of these belts was made at the works of Messrs. L. Sudicatis & Co., from a 250 h.p. steam engine to a three-phase generator, when a leather belt 600 mm. in width was replaced by a steel band of only 100 mm. width. Apart from this reduction in width and the resulting saving of space, a considerable reduction in the width of the pulley was obtained, which in its turn resulted in a material cheapening of the latter, as well as in a reduction in the weight of the pulleys and in an easing of their bearings. In fact, flying pulleys can be used in many cases in which the provision of double bearings had so far been quite indispensable, such as in the case of large



STEEL BELT DRIVE FROM GAS ENGINE TO DYNAMO.



LOW SPEED STEAM ENGINE DRIVING A DYNAMO BY A STEEL BELT.

dynamos and electro-motors. Furthermore, there is a possibillty of deriving from flying pulleys a far greater amount of energy than has hitherto been possible. Another advantage is the reduction in the distance separating the shafts, ensured by the use of steel bands, the action of which is due to their own tension instead of to tension weights. This reduction, in the case of a gearing not materially differing from 1 : 1, can be increased until the pulleys are nearly in contact with one another. This permits a saving of about 15 per cent. as compared with rope transmission and at least 5 per cent. as compared with belt transmission, the more so as the remarkable efficiency of a steel band drive is maintained in the case of small loads.

The most important advantage of a steel band drive over other methods of power transmission is in fact the high efficiency, due to the slight slip. While transmission is accurately effected at the ratio of pulley diameters, thus simplifying the ratios of transmission, the losses of energy due to the steel band remain below 1 per cent., thus becoming practically negligible. The saving resulting therefrom will amount each year to a multiple of the first cost of the whole installation, so that the expense of conversion is repaid within a few months.

As these bands are made of special hardened steel, their length is constant, thus dispensing with any re-adjusting.

Another feature of the steel belts is their ability to run absolutely true without guides, no appreciable oscillations being noted even in the case of very rapid rotation. Steel band drives thus allow of high speeds, 100 metres per second having been easily reached in connection with experiments recently made, while such figures as 50 metres

per second may be said to be quite moderate.

Professor Kaemmerer, of the Charlottenburg Technical High School, recently tested in his laboratory a steel belt 10 mm. wide and $\frac{1}{2}$ mm. thick on two pulleys of 2·5 metres diameter each. This steel belt was found to convey a maximum power of 146 h.p. at a tension of 200 kg., and the maximum slipping was ·15 of one per cent. The loss of power due to the belt, even with small loads and great speeds, was quite immaterial, generally remaining within the limits of experimental error. No stretching of the belt during the experiments could be ascertained.

According to a certain law, borne out by practice, a given pulley diameter should not be exceeded in the case of a given peripheral force. As a consequence of this, a certain minimum speed should be used in transmitting a certain power with a given high number of revolutions. When stated in practical terms, this law means that speeds as high as possible are generally found most advantageous. In the case of gas engines, the power of which is derived from a fly-wheel, resulting in very high speeds of rotation, especially favourable results have therefore been stated, due primarily to the extraordinary surplus outputs which are rendered possible in the case of maximum loads on the machine.

Practically all the private electricity works of the city of Berlin, which had so far been equipped with leather belts, have adopted the new system of power transmission, which has given every satisfaction. While the first cost of steel bands, in the case of large-size plants, is considerably lower than that of equivalent leather belts, the permanent reduction in the cost of operation is of far greater importance. Safety devices are fitted to these bands far more easily than to leather belts, though the danger attending their operation is much less than in the case of the latter.

While no material effect is produced by projected oil, the co-efficient of friction not being reduced to any considerable extent, water will produce a material reduction in friction, and steel bands in the case of damp plants should therefore be submitted to higher tension.

A Hydrogen Peroxide Cell.

Two papers have been presented before the American Electro-chemical Society by H. T. Barnes and G. W. Shearer in conjunction with H. M. Tory and G. H. Cole, in which the results of experiments on the effect of dissolved gases in water on metal surfaces have been given. In the second paper a cell was described which consisted of electrodes of aluminium and magnesium in a solution of aluminium sulphate, to which some hydrogen peroxide was added. Aluminium behaves in a peculiar manner in contact with dissolved air, or oxygen, and becomes electro-negative to a similar aluminium electrode in water free from dissolved air. Magnesium does not show this effect: hence a cell with the two metals for electrodes has a comparatively large E.M.F. developed when dissolved air or oxygen is introduced. The effect is considerably increased by adding hydrogen peroxide. Acting on the suggestion of Prof. Bancroft, tests were applied to the water in which clean aluminium had stood for a few hours, and a measurable quantity of hydrogen peroxide was detected. This was developed from the action of the dissolved oxygen on the aluminium, probably according to the following reaction, also suggested by Bancroft:—

$$2Al+6H_2O+6o=Al_2(OH)_6+3H_2O_2.$$

The amount of yield of the peroxide was considerably increased in several ways. Without dissolved air no trace of peroxide was observed. The generation of the hydrogen peroxide explains the abnormally E.M.F. developed between two metals so close together in the electrochemical series.

Messrs. Crosby Lockwood & Son send us the first number of a quarterly circular of engineering and technical literature (classified under subjects), published by them at their recently opened technical book room in Victoria Street. The circular contains all the most important works in engineering science and technology published during the past three months in England and in America, and as it will be repeated every quarter, should certainly prove of the greatest assistance in the offices of British engineers.

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Electric Power for Marine Propulsion.

By W. P. DURTNALL.

The paper on this subject with which Mr. Durtnall opened the current session of the Institute of Marine Engineers raises the very important question of the economy that may be effected by the application of the electric drive in marine propulsion. A good case is made out in its favour by the author, but there are many points involved which, until the full light of discussion has been shed upon them, must render their final acceptance doubtful. (Ed. *E.R.*)

FEW of the subjects which are to-day engaging the attention of the engineering world are comparable, either in scientific interest or in practical importance, with the generation and transmission of power for marine propulsion.

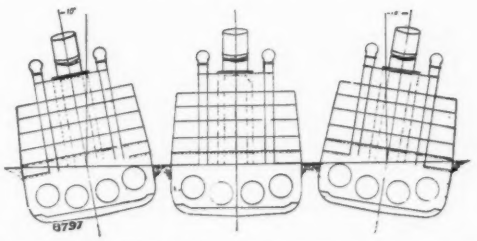
To design and construct a modern vessel which shall afford wholesome living accommodation and also provide sufficient warehouse room for merchandise and to be capable of propulsion from place to place at a given speed, and to be as safe against the perils of accident and tempest as human foresight can make it, is a problem which, if there was no experience to guide, would probably present as great difficulties and complexities as any one would care to attack. Such, however, with the experience of the past to guide him, is the work of the naval architect. The first object aimed at is to propel a floating body through water at a certain speed, the second is to construct the propelling apparatus that the motion may be readily reversed or reduced in speed, and the third to adopt such an arrangement of propellers and motive power as shall be convenient for disposal in the floating body, and the economical working of the same in service conditions. Such comes within the sphere and work of the marine engineer. Since about sixty-four years ago, when the first screw-propelled vessel crossed the Atlantic, a vast improvement has taken place in this method of propulsion, and all along this line of progress has seen the development of improved mechanical engineering, and some very beautiful pieces of ingenuity have been devised and put to work with well known results, as witnessed by the change from the engines of the *Great Britain*, consisting as they did of two cylinders, each 88 ins. diameter and 72 ins. stroke. These worked at a steam pressure of 6 lb. per sq. in., ran at 18 r.p.m., and drove by means of chain gear of 3 to 1 ratio a six-bladed propeller at 54 r.p.m., and took about fifteen days to cross from Liverpool to New York.

Since that time have been introduced a large number of designs of steam marine engines, including the application of compound, triple and quadruple expansion engines, and now we may add turbines.

A great deal of investigation has been carried out with that interesting piece of apparatus the screw propeller, when working under various conditions; but although many formulæ for finding the power necessary for a given vessel speed have been produced, these formulæ are of little real value unless the designer knows all the data of ships of similar form, size, and speed.

But the advent of the practical application of the marine steam turbine, by Mr. Parsons, and also that splendid and clever piece of apparatus, the torsion meter, by Messrs. Denny, accurate measurement can now be taken of steam used, and horse-power developed at the propeller. Doubtless a still closer investigation will take place, and the generally improved design of propellers will follow the actual tests which, under

real service conditions, can now take place. The object of this paper is to bring forward the great possibilities of electrical power transmission and speed regulation as applied to steam-propelled vessels, when looked at also from the commercial aspect, and especially to point out the low operating cost that is possible, which may serve to show the electrical transmission of power for marine work to be quite within the range of possibility.



A VESSEL HEELED OVER 10 DEG. SHOWING THE UNEQUAL IMMERSION OF PROPELLERS AND CONSEQUENT EXTRA RESISTANCE TO PROPELLER ROTATION. SPEED CAN BE SYNCHRONISED, THUS SAVING POWER AND GIVING IMPROVED PROPULSION.

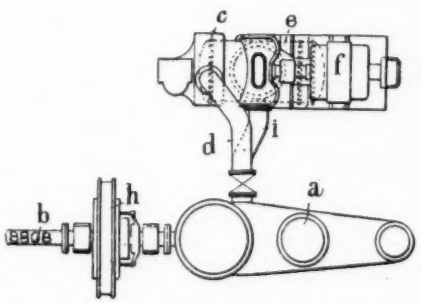
GENERATION OF POWER.

Steam still holds the leading position as the working fluid in heat engines, therefore its economical generation is of the highest importance and the construction of boilers is a study for all engineers.

The question as to what type of boiler is best suitable for marine work is, and has been, a very disputed one, and different engineers still hold very divided opinions on this subject. No decision can, however, be arrived at on this point without a clear knowledge of the conditions under which the boilers have to work, and also the total amount of power that has to be provided. Some of the important points called for, however, are simplicity of construction, supply of dry steam, rapidity of raising steam, and capability of over-working, or being forced for short or reasonable periods, and last, but not least, light weight. Although the cylindrical marine type of boiler has done, and is still doing, good work, there is no doubt that, on account of unequal heating effects, causing racking strains, and inefficient heating caused by unbroken masses of hot gases, lack of circulation, its great bulk, and weight, will in the end tell against its extensive use in future in these days of keen competition and low freight rates: and those owners who would desire to cut down working expenses would do well to look further into the merits of water tube and other efficient steam generators for use in the mercantile marine service. In large electricity supply stations on land most successful application has been made of these improvements in boiler house equipments.

OIL FUEL.

Oil fuel will no doubt in the end find its own ground, and some of the features that strike one most forcibly in connexion with this fuel is the absence of dirt and cinders, considerable saving in stoke-hold staff, by reason of the ability to move the fuel by pumps and pipes, instead of stokers and trimmers, &c., and the absolute control of the heat that can be arranged, and many other commercially good points. Some very remarkable tests have recently been carried out with the application of oil fuel, on the two sister French battleships *The Patrie* and *The Justice*, each of 18,500 h.p., using large tube Niclause water-tube boilers. The



SYSTEM BY PARSONS. RECIPROCATING ENGINE EXHAUSTING INTO L.P. TURBINE WHICH DRIVES ELECTRIC GENERATOR, SUPPLYING CURRENT TO MOTOR ON ENGINE PROPELLER SHAFT.

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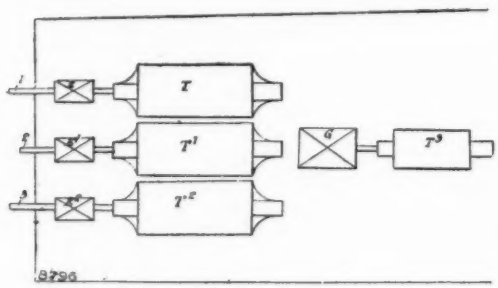
tests were carried out in very boisterous weather and showed conclusively that, when necessary, boilers may be forced above their normal working conditions with oil fuel, a virtue that it is desirable to have, although possibly not always taken advantage of under the normal steaming conditions.

PRIME MOVERS.

There is no doubt that until a satisfactory internal combustion engine, of comparative large power, is produced that the steam turbine will remain as a simple, light, small and efficient prime mover, and to be so, it must of a natural necessity run with a good condensing plant and at high speed. During the last twenty years the steam turbine has been developed in various forms and applied on a large scale to the generation of power, for electricity supply, marine propulsion and other purposes. The turbine is in several ways an almost ideal motor; it is easy to open up and repair, and is especially suitable for use with high superheated steam owing to the practical freedom from distortion, &c., of its few working parts, and to the conspicuous absence of lubricated surfaces exposed. It gives a uniform torque, and is, at least in some cases, highly efficient under great variation of load, as witnessed by its successful application in important generating stations, working with tremendous loads, for railway and electric lighting service.



A SWISS PROPOSITION USING THE DIRECT COUPLED TURBINES AT TOP VESSEL SPEED AND A SEPARATE TURBINE DRIVING AN ELECTRIC GENERATOR SUPPLYING CURRENT TO MOTORS MOUNTED ON THE MAIN TURBINE SHAFTS FOR LOW VESSEL SPEEDS OR REVERSE.

Its direct application for marine propulsion has secured a very strong hold, but in this case it labours under a few but important disadvantages. It has to be direct-coupled to the propeller, and to be designed so as to run at very low speed in order to permit of the use of a propeller of high propulsive efficiency, consequently the weight per b.h.p. developed is increased to a very large extent, and owing to the large diameter of rotor and casing, proportionately large blade clearance must be allowed in order to meet the conditions of expansion and contraction, &c., with consequent higher steam leakage and consumption per horse power of work developed. Another disadvantage of this application is the difficulty of reversing for manœuvring and going astern, and under those conditions it is not economical in steam, when working below full load and speed. (In the tests of *The Lusitania*, steam used by the turbines only including auxiliaries, was at 25·4 knots, 14·46 lbs. and at 15·77 knots, 26·53 lbs. of steam per shaft h.p.). This inconvenience, although of perhaps little importance with steamships making long continuous runs, is very important for those making short voyages, starting and stopping, and manœuvring in and out of harbour several times a day, or for ships of war, in battle or manœuvring in squadrons, and in order to get these very necessary qualities, separate astern turbines have to be installed and carried, but with only generally about one-third the ahead power, and these usually only applied to two out of three or four shafts as the case may be

Such an arrangement cannot be looked on as very satisfactory, as part of the machinery is always running idle in either direction and dead weight is therefore considerable for that reason alone. Furthermore a full-power speed is not possible at reverse, and the

reverse turbines are generally not so economical as the ahead turbines when running under work, as regards steam used per b.h.p. of work done, so that in order to get full power and speed astern, it would be necessary to install a duplicate set of turbines. Obviously the weight would be increased, but even then the safety would be of possibly more importance than the increased weight. It has been stated that as at present arranged the steam turbine-driven ships, on short voyages, lose in landing most of the time gained by increased speed in the passage. It will therefore become quite evident that in order to secure the future complete success of the steam turbine as used for ship propulsion some means must be provided to allow the turbine to run at high speed, and the propellers at comparatively low speed, and so secure economy in both cases, and also to provide reverse motion for all shafts.

MECHANICAL GEAR.

This has been tried in connection with small power turbines, but the results, generally speaking, have been far from satisfactory, on account of the noise and heavy cost of up-keep. In the case of high power transmission by gearing the noise would be insupportable, and the upkeep abnormally high, owing to fractured bearings and gear wheels, &c., and complications would probably arise when dealing with large powers owing to making the necessary provision for reverse motion and propeller speed regulation.

HYDRAULIC GEAR.

This would be of possible interest, but it is questionable if reasonable efficiency could be secured and vibration avoided, and owing to sliding parts, &c., wear and tear would in very large powers become very pronounced.

COMPRESSED AIR.

Although this method of power transmission has been extensively tried in small powers, it involves apparatus of such large dimensions that it would require the space of ordinary reciprocating engines to utilise the energy for driving propellers at low speeds, and for that reason alone could not be considered a practical solution, and furthermore either of the last two methods would not secure the utmost propulsive efficiency for a given amount of steam power, especially in rough weather.

ELECTRICAL POWER TRANSMISSION.

This method seems to be the one in which the greatest possibilities lie; it has been proved by extensive practice that electrical power transmission has no successful competitor commercially, even over very long distances; and by its means we can get the very thing that is wanted for marine propulsion—the very elements that are required in order to take advantage of high speed turbines thus saving turbine weight and also securing high economy in steam by utilising these to drive electrical power generators. The current so generated can be used to supply low speed electric motors, coupled to suitable propellers which can be so calculated as regards power and speed that high efficiency can be secured by use of moderate speed large bladed propellers. Further, this method of power transmission does not necessitate the cost of installation or operation of reverse turbines, as although the generators and turbines, fitted as prime movers, would run always in the same direction as regards speed rotation, the electric motor possesses the very thing that is required, namely, that it will do its work equally well, and can be efficiently run, in either direction, and the speed and direction can be instantly changed to suit all conditions met in practice. This very important feature can be utilised with the utmost economy even at the very lowest speeds and powers.

Most engineers are well aware that the electric motor is a very flexible and efficient machine, and has the important quality, like the steam turbine, that it can stand a very severe overload for short periods without damage. The importance of this feature will appear

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more prominently later and this very feature for marine propulsion in rough weather will be evident to the most sceptical, and pleasing to the sympathetic expert.

Owing to the very fine control which is possible, advantage can be taken of complete operation from the bridge, or other suitable position, by means of motor operated switches, the large power conductors need only be broken, as when under no voltage conditions, and can be of the very simplest design, although controlling such large powers as will be met with in electrical marine engineering, and there are many points of real interest which have possibly been hitherto unlooked for.

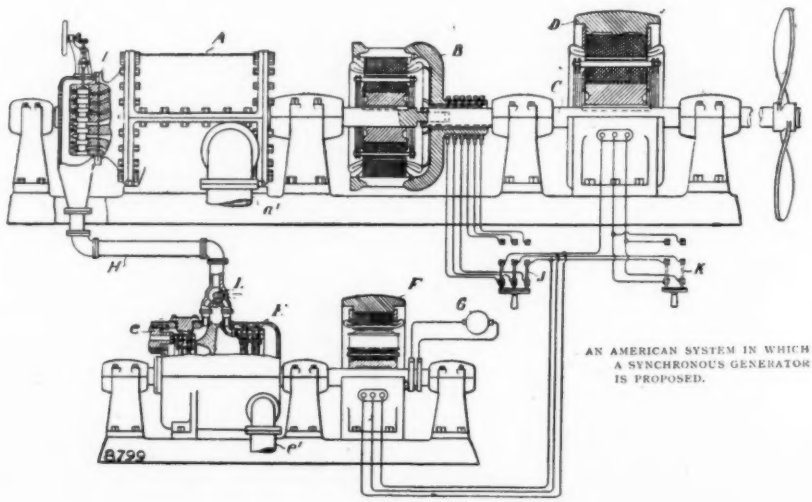
I might here say that this important scheme has been partly discussed and criticised at various times recently, and that several dissenting opinions of considerable weight have been expressed in electrical engineering circles where the marine engineering side has not been thoroughly understood, and also in marine engineering circles where the electrical proposition has not been properly grasped; nevertheless it is with absolute confidence that I bring this matter more closely before you, and we shall probably soon have the opportunity of seeing in how far this confidence is justified.

ITS PRACTICABILITY.

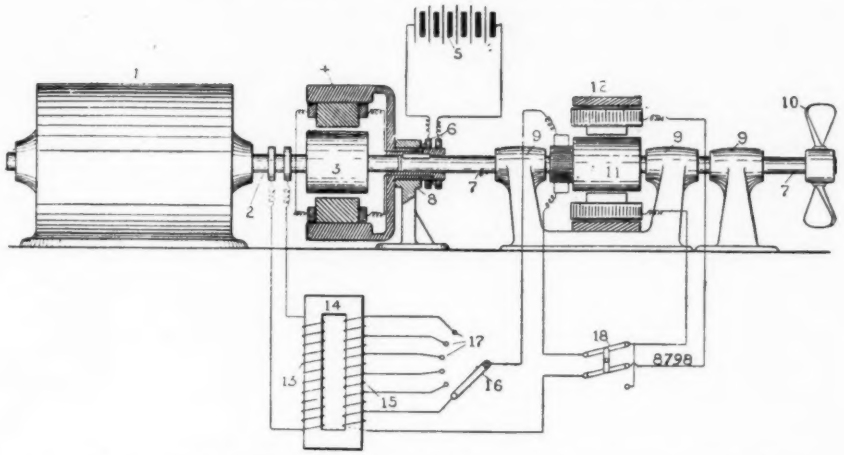
In the creation of an absolutely new system of marine power transmission such as we are considering, the first question that arises is of course as to its practicability, that is to say, will the devices used accomplish what is expected of them, and will they do it properly? This question has happily been settled some time now, and it is a thing not now to be queried, the practical commercial success of the very large electrical power transmission plants that are operating continuously in all parts of the world are sufficient to justify the answer.

ECONOMY.

The next and all governing question arising is that of economy, formulated into the old, old question—will it pay? The answer to this was at first considered only from the somewhat narrow standpoint of comparing the efficiency, weight and cost of the shaft from the prime



AN AMERICAN SYSTEM IN WHICH A SYNCHRONOUS GENERATOR IS PROPOSED.



AN AMERICAN ELECTRICAL MARINE PROPULSION SYSTEM USING SINGLE-PHASE ALTERNATING CURRENT MACHINES.

mover to the propeller, and from that aspect alone, electrical or any other media of power transmission cannot compete successfully with the straight through mechanical drive; but, however pleasing that may appear to the mechanical engineer it is not the owner's or the manager's point of view. Their view generally takes the line of "what does it cost to carry passengers or freight a given distance?" and when looked at from such broad views, it is quite an interesting question as to whether we are, with the present methods, utilising both coal and material to the best advantage. It might be here pointed out that the electrical power transmission proposition, brings the simple and reliable steam turbine within the practical range of its application to both fast passenger liners and combined passenger and cargo steamer, as well as slow cargo tramps.

ITS APPLICATION.

Realising that the construction and working of modern electrical machinery for power transmission may not be everyday practice with all who read this communication, I will briefly describe and illustrate some latest applications. In doing so, I may state that, after the very closest investigation, it is my opinion that for marine propulsion, electrical power transmission can be only successfully carried out by means of polyphase alternating currents with synchronous generators, and squirrel cage induction motors, not only on account of the great simplicity of these machines, but on account of their low cost and their low weight per horse power developed. Again, considering the immense power to be handled, it is my opinion that as to continuous current and other forms of machines embodying the use of commutators and brush-gear, their use would be a matter practically of impossibility; besides, such complications would not secure the low cost of maintenance which is absolutely necessary. It has been suggested to utilise a synchronous type of turbo-generator, with squirrel ca[illegible] type of motor, which are no doubt very easy and suitable for parallel running, without synchronising gear, and absence of rubbing contacts. But they are expensive, and less efficient, partly owing to large exciting current, and these machines are very rarely used in gocd practice.

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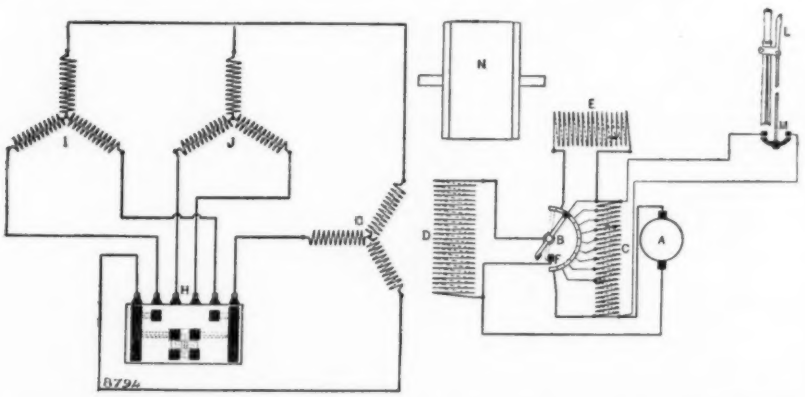
POLYPHASE SYSTEM ADVOCATED.

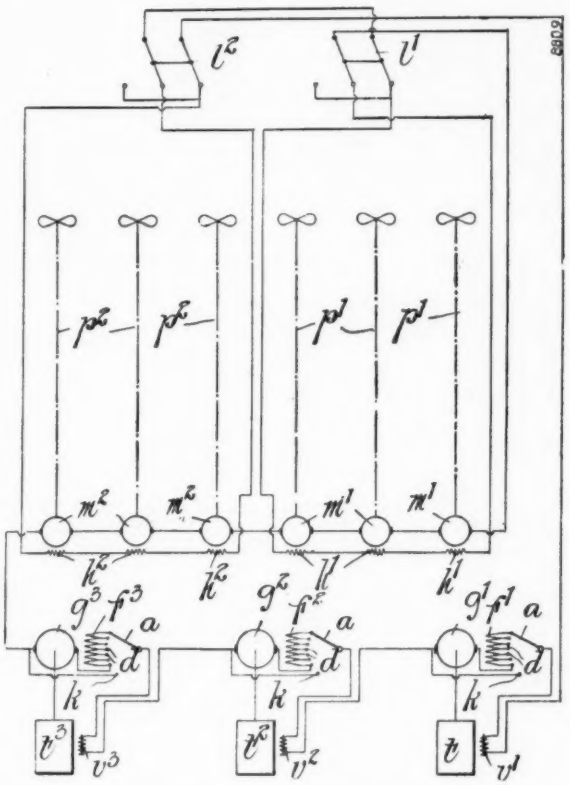
In the polyphase system, with revolving field alternators, we have all those valuable features which are required for marine purposes, and that is what we will now deal with. In this type of alternator, the armature is stationary, and the armature windings are arranged in slots on the inner face of the armature structure, the latter forming a closed ring inside of which the multipolar field magnet revolves. The armature structure consists of an external frame of cast steel supported on a bedplate; a core consisting of a ring, built up of relatively small stampings of sheet iron, dovetailed into the external frame, and pressed together between two flanges by hydraulic means and bolts. The external frame in this type of alternator does not to any perceptible extent carry lines of force, that is to say, it does not form part of the magnetic circuit but serves only as a support for the laminated armature core. By this construction it will be observed that as the main current is generated it can be taken right off from the stationary winding. The revolving field is constructed by a cast steel centre, forming the yoke of a, say, 4 pole magnet, on which is fixed the exciting coils, and these are connected to slip-rings, which receive the exciting current from a small direct-current dynamo, the armature of which is generally mounted on the end of the main shaft. The current which this machine supplies is the only amount that is used by the revolving parts of the alternator, and is small as compared with the total output of the generator, usually about 2 per cent., but varies according to circumstances. It is, however, of importance to note their exceptionally high efficiency as converters of mechanical into electrical energy which varies in the case of small sizes such as are used in factories, to large sizes such as are used in railway traction generation stations, from 85 per cent. to 98 per cent., and their weights per k.w. output for continuous rating, between 35 to 22 lbs. according to speed and other circumstances, while the steam consumption per k.w. hour in 7,500 k.w. sizes at, say, 750 r.p.m., running condensing and at 160 lbs. steam pressure, with 150° superheat at the stop valve, with about 27½ in. vacuum is about 13·5 to 14 lbs. (including auxiliary plant). A 2,000 k.w. set running at 1,500 r.p.m. under similar circumstances consumes about 15·5 lbs., and it is also interesting to note that a 500 k.w. set at 3,000 r.p.m., uses only 23 lbs. of steam per k.w. hour.



THE HURT-DURTNALL POLYPHASE ALTERNATING CURRENT SYSTEM AS APPLIED TO MARINE PROPULSION IN CONJUNCTION WITH INTERNAL COMBUSTION ENGINES, PROVIDING A REVERSE AND THREE-AHEAD SPEEDS. CONTROL FROM BRIDGE.

For generators of equal output, the high speed steam turbine-driven, low periodicity type is best as regards ease of design, low weight, and initial cost, as well as requiring much lighter foundations, with consequent less initial cost in fitting and, what is most important, considerable less head-room and floor space and proper parallel running.

Satisfactory continuous current turbo-generators can only be constructed, in comparatively small sizes, and even then have recourse to either commutating poles or compensating windings, preferably the latter, as these prevent field distortion, and consequent flashing over, of high voltage current, from brush to brush. This type of generator is not to be looked on as a suitable machine for the purpose of providing current for main marine propulsion, as compared with the previous type of generator.

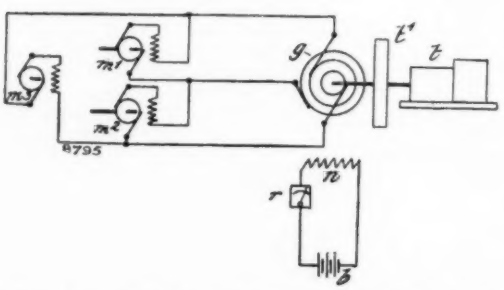


HURT-DURTNALL D.C. SYSTEM WHERE SIX PROPELLERS ARE PROPOSED. ONLY USED FOR SMALL POWERS.

As regards the three-phase alternating current induction-motor, this has become very popular in recent years, mainly owing to its powerful starting torque, light weight, and its freedom from commutators and brush-gear. A burnt-out armature, the perpetual source of dread in electric motor operation or practice, is practically unknown in this type of machine, even when put to very severe service, indeed, its depreciation under fair conditions is as low as in any other type of mechanical revolving machinery, and owing to its peculiar running characteristics it is especially suitable for marine propulsion work. It is very compact, and is noted for durability and simplicity; it also has the important qualification of low cost of structure, combined with great mechanical strength. The absence of commutators and brush-gear is an immense advantage, and as there is therefore no sparking limit as in other forms of motors, the consequence is, that the output per unit weight is much greater in large size polyphase induction motors, than in, say, a direct currect machine. It is quite within the range of possibility, to design and construct these motors for marine work, of from 1,000 to 10,000 h.p., which would weigh from 35 to

20 lbs. per h.p. developed, and this for continuous rating, and without sacrifice of any efficiency, which would in these cases be about 93 to 97 per cent. It is also interesting to note that unless considerably overloaded, an induction motor will run quite cool compared with other motors of the same weight and output; this being to a great extent due to the large section that can be given to the windings, whilst the laminated character of the iron facilitates ventilation.

Although polyphase induction motors are termed non-synchronous, it should be borne in mind that there is always a tendency towards synchronism. The speed of an induction motor is, in fact, almost independent of the load, the variation in speed of squirrel cage motors, from no-load to full-load, seldom exceeding, even in small sizes, 5 per cent., and in large sizes would probably not exceed 1 per cent. Generally speaking, it is not too much to say that while the commutator motor will always be an electrical apparatus requiring more or less skilled attention (especially in large units), the polyphase squirrel cage induction motor, being without brush-gear or commutators, &c., can practically be termed a piece of mechanical machinery requiring no skilled and very little un-skilled attention, and consequently the maintenance of same is of the lowest possible amount. It is also of more than passing interest to note that the main working current passes only through the stationary parts of the motor, facilitating strong and reliable insulation for the conductors and other valuable and practical points which I am sure will be appreciated by the deep-thinking and studious marine engineer.



A GERMAN SYSTEM OF ELECTRICAL MARINE PROPULSION WITH SINGLE-PHASE COMMUTATOR MOTORS.

ELECTRICAL AND DIRECT DRIVE COMPARED.

It is interesting to compare the various published steam trials that have taken place, showing the results that are possible with electrical power transmission with high-speed steam turbines, &c., and to especially show the saving in steam that is possible.

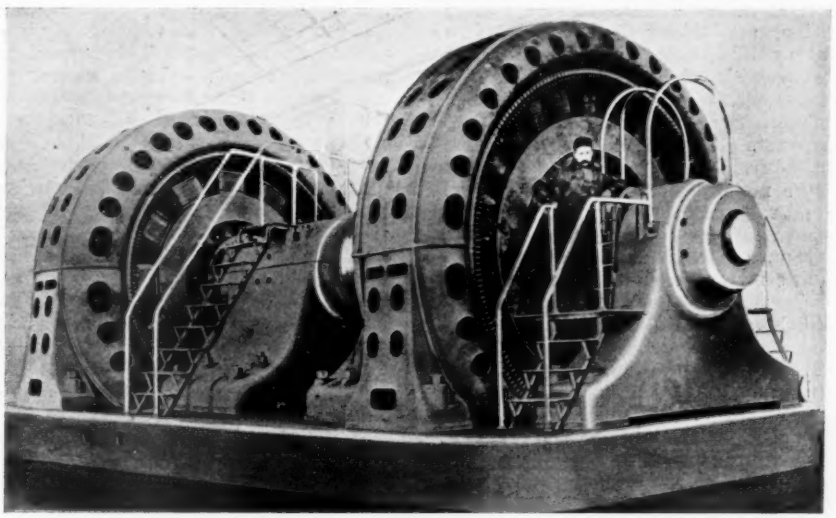
Let us assume that we wish to know what will be the steam capacity of the boilers for a vessel fitted for electrical transmission, for four propellers each requiring to rotate them 1,000 b.h.p. at 250 r.p.m., the motors to be of the polyphase induction type, with squirrel cage rotors, and with stators wound for full, half, and quarter speeds. The generators would, in this case, consist of two turbo-alternators and exciters capable between them of generating and supplying 3,250 k.w., and running at a speed of 1,500 r.p.m. with steam at, say, 150 lbs. pressure and 150° F. superheat. These alternators would be, say, 2 pole machines; therefore, if the motors are wound for 12 poles (for top speed) it will be equal to 6 to 1 reduction in turbine for propeller speed. For half-speed the second winding would be arranged for 24 poles, 12 to 1 reduction with two sets of windings in parallel, and for quarter speed, this winding would be arranged for 48 poles, 24 to 1 reduction. With these windings in series the synchronous speeds would thus be full speed 250, half speed 125, and quarter speed 62½ r.p.m.

For the top speed the above turbo-alternators would be coupled up in parallel, and when supplying the motors with current would generate 3,250 k.w., and the consumption

would be, say, 16 lbs. per k.w., or 52,000 lbs. of steam per hour, or 13 lbs. per shaft h.p., which compares, in my opinion, very favourably with what would be required with direct-coupled turbines working under similar speed and circumstances and would be more in the order of 22 lbs. per shaft h.p., or 88,000 lbs. Therefore the difference in steam consumption is 36,000 lbs. per hour, representing a saving of no less than 41 per cent. in boiler capacity comparatively. less than 47 lbs. per shaft h.p., equal to 28,200 lbs. of steam or, under these circumstances, there would be a saving of no less than 10,440 lbs. per hour, equal to 37 per cent. saving in steam at half-vessel speed (and I have estimated on the easy side for the direct-coupled turbine).

WEIGHTS OF PLANT.

Assuming these estimates to be approximately correct, it may be asked,



THE ABOVE ILLUSTRATION SHOWS A LARGE ELECTRIC MOTOR DRIVING A GENERATOR. THE TOTAL AMOUNT OF WORK THAT THE ABOVE WOULD BE ABLE TO DEAL WITH, BOTH COUPLED AS MOTORS, WOULD BE NO LESS THAN 16,000 B.H.P. OR EQUAL TO ONE SHAFT OF THE "LUSITANIA." THE TOTAL WEIGHT OF THE MOTOR AND GENERATOR IS 155·2 TONS.

Now at half speed we will close down one of the turbo-alternators altogether, and we shall probably only require, say, 600 shaft h.p. at this speed; therefore I will estimate the efficiency of the motors at this half-speed and load 60 per cent.—740 k.w. The turbo-generator would use, say, 24 lbs. of steam per k.w. hour, with this load, but would run at top speed, although at half-vessel speed, and this is equal to 17,760 lbs., while the direct-coupled turbines would each run at half-speed, and the consequent steam consumption would be not

what will be the relative weights between the two systems? We will take first the four motors—

	Tons.
4,000 b.h.p. at 35 lb. per h.p. developed, say	62½
Conductors, switch-gear, &c. ... ,,	6
Two turbo-generators as above ... ,,	70
Condenser for above ... ... ,,	19
Steam piping, &c. ... ... ,,	13
Air pump and motor ... ... ,,	6
Circulating pump and motor ... ... ,,	7½
	184

While the weight of the direct coupled turbines and part of the propeller shafts,

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shaft tunnels, &c., including condenser, steam-pipes, &c., air and circulating pumps—which would have to be arranged to efficiently deal with the 88,000 lbs. of steam—would be at least (taking the speed of the turbines at 250 r.p.m.) 148 tons, showing that the electrical machinery would be about 25 per cent. heavier, but it is here necessary to point out that that only applies to the plant from stop valve to propeller shaft connections. We will now look into the possible saving in operating costs and weight at the other side of the stop valve, and taking the data that have been published, as regards the weights of cylindrical boiler, stoke-hold equipments, &c., which are as follows, when taking reciprocating engined vessels into account. It has been stated that good cylindrical boilers, including small and large mountings, fire box and funnel (boiler empty), with forced draught, pipe work, including all pumps, water, steam, and exhaust pipes, gratings, platforms, &c., weight per i.h.p. in boiler room reaches 180 lbs. Therefore, the weight of the boiler room equipment of a vessel in which would be installed, say, two reciprocating engines running condensing would approximately be as follows:

Taking 180 lbs. boiler equipment weight per i.h.p., then 4,700 i.h.p. with a mechanical efficiency of 85 per cent. would equal 4,000 b.h.p.=377 tons, and in order to get at the steam consumption per ton of boiler weight we will allow, say, 16 lbs. of steam used per i.h.p. including steam required for auxiliaries and losses due to radiation, &c., therefore=75,200 lbs. of steam, or equal to 200 lbs. of steam per hour per ton of boiler-room equipment. Under these circumstances the boiler-room equipment would weigh for the 52,000 lbs. of steam that will be required for the electrically driven vessel, 260 tons; while for the direct coupled turbine driven vessel, the boiler equipment would weigh not less than 440 tons, or a saving in weight in boiler-room equipment for the same propeller h.p. of not less than 40 per cent. or 180 tons.

COAL CONSUMPTION.

Now, as regards coal consumption, and comparative saving in this direction, we will take it that with hot feed, clean flues, and with good Welsh coal, that it is possible to evaporate, say, 10 lbs. of water per lb. of coal burnt, so that we have in the direct coupled turbine vessel a coal consumption of 8,800 lbs., and in the case of the electrical vessel 5,200 lbs., or a saving of 1·6 tons per hour, which equals in a ship running for six days a nett saving in favour of the electrical scheme of no less than 230 tons less dead weight and, what is very important, running cost. This important matter will be surveyed with somewhat close interest by cargo vessel owners, as it may be at the same time observed that the propellers are run at about the same low speed as is necessary and usual in these slow vessels, in order to secure economy at the propeller, and for the usual speed of such cargo vessels, it is possible to further reduce the speed of the propellers should it be considered necessary to suit the ever-varying conditions that will possibly be met with in practice, and this could be secured by slight increase in the weight of the motors only, the generating plant weight remaining the same.

The system is very suitable for conversion of existing single-propeller vessels, while in twin-propeller ships a certain advantage is secured in economical operation by the use of one power generating plant working twin screws, with their various advantages, certain security and ease of control.

There are many other valuable points that might be put forward in support of this interesting application of electrical power transmission. The above conclusions must not be considered as being perfectly definite, on account of the widely different conditions that would be met in modern practice; but this paper is chiefly put forward to open up the way for the serious consideration of naval architects and engineers, in the hope that a new field of operations can be made for the electrical engineer, with the friendly co-operation of his marine

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colleague, to the advantage of the ocean carriage of passengers and goods.

RESULTS OF TEST OF TWO AMERICAN VESSELS.

	Nantucket.	*Governor Cobb.*
Date of test ...	Feb. 7th, 1904	April 18th, 1907
Duration of test—boiler	20½ hrs.	8 hrs.
Duration of test—engine	20½ hrs.	4 hrs.
Boiler pressure (average gauge)	147·3 lbs.	128 lbs.
Quality of steam (sampled at drip)	98·8	97·3
Barometer... ...	14·7 lbs.	14·7 lbs.
Temperature of air pump discharge	—	110° F.
Temperature of feed water	209·4° F.	213° F.
Kind of coal used	Georges Creek	Cape Breton
Moisture in coal ...	2 per cent.	1·9 per cent.
Ash and clinker in coal	7·6 per cent.	6·8 per cent.
Draft at blowers ...	Natural	2·1 ins.
Number of boilers (single - ended Scotch)	4	6
Total grate surface	320 sq. ft.	323 sq. ft.
Total heating surface approximately	10,150 sq. ft.	12,000 sq. ft.
Ratio, heating to grate	31·7	37·2
Coal fired per hour	5,135 lbs.	8,050 lbs.
Water fed per hour (average during engine test) ...	45,844 lbs.	85,710 lbs.
Coal burned per square foot grate surface	16 lbs.	24·64 lbs.
Maximum revolutions	—	p. 475, s. 460, c. 440
Corresponding total shaft h.p. ...	—	4,100
Average revolutions	74·05	447
Average total h.p.	2,362	3,747
Steam for auxiliaries	—	38,360 lbs.
Steam per i.h.p. per hour, total ...	19·41 lbs.	—
Steam per b.h.p. per hour, total ...	—	22·87 lbs.
Propelling machinery only	—	19·74 lbs.
Speed (average) in knots	15·00	17·21
Type of engine ...	Reciprocating	Turbine
Vacuum in inches	25	27

DIMENSIONS.

Length between perpendiculars...	274 ft.	290 ft.
Beam moulded ...	42 ft.	51 ft.
Draft	15 ft.	14 ft.
Displacement ...	2,700 tons.	—

THE QUEBEC BRIDGE was recently the subject of two important reports to the Dominion Parliament representing the majority and minority views of a committee of inquiry. According to the *Engineering Record*, the majority report states that the Quebec Railway and Bridge Co. fully complied with all its agreements under which the Dominion Government agreed to guarantee its bonds. When the Government pays all the outstanding claims against the company it will possess the whole bond issue of $6,678,000 and have an undivided lien on the approaches, which cost over $1,000,000; on the substructures, which cost over $1,000,000, and on delivered material estimated to be worth about $1,000,000. The minority report attacks the manner in which the Dominion's interests were managed, and states that all it has to show for an indebtedness of $6,322,008 is "some stone piers and abutments, some iron material and some land as approaches." The unofficial announcement of the Government's intentions regarding the structure is that the work will be turned over to the Transcontinental Railway Commission, to be completed as rapidly as practicable, under the supervision of an international engineering board of three engineers. The structure forms an essential link in the great railway projects to which the Government is committed, and in view of the limited time remaining for its completion, the existence of the costly substructures and approaches, and the absence of any serious criticism of most features of the design of the fallen structure, it would not be at all surprising, states our contemporary, if the plans adopted for the new work were substantially the same as before, except as regards details of the lower chords and some minor members.

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The Design and Construction of Mechanical Calculators.*

By WILLIAM J. GOUDIE, B.Sc., A.M.I.Mech.E.

THE Board of Trade formula, for determining the diameters of the shafting of marine engines is an illustration of the type of expression which is neither factorial nor quasifactorial, but which may be modified by preliminary adjustment so as to bring it within the latter category.

In accordance with the Board of Trade notation it is written :—

$$S = \sqrt[3]{\frac{C\ P\ D^2}{f\left(2 + \frac{D}{d^2}\right)}}$$

where,

S = Shaft diameter in inches, ranging from (say) ...	2·75	to	20
C = Length of crank, in inches, ranging from (say)	3	,,	30
P = Boiler pressure in lbs. per sq. in. abl., ranging from (say)	50	,,	250
D = Diameter of L.P. cylinder in inches, ranging from (say)	10	,,	100
d = Diameter of H.P. cylinder in inches, ranging from (say)	5	,,	40
f = Constant, ranging from (say)	740	,,	1,295
$R = \frac{D^2}{d^2}$ = Total cylinder ratio, ranging from (say)	2·5	,,	12

The value of f is made to depend on the angle between the cranks. In the "rules" D^2 and d^2 are to be taken as the sum of the squares of the L.P. or H.P. cylinder diameters where two or more cylinders are used in place of a single cylinder. As it is very seldom in modern practice that more than one H.P. cylinder is used it is hardly worth while making provision for this condition. As the total L.P. volume is still, however, frequently divided, provision is made for the substitution of two equivalent L.P. cylinders. For mechanical manipulation the equation is written in the form:—

$$S = \frac{C^{\frac{1}{3}}\ P^{\frac{1}{3}}\ D^{\frac{2}{3}}}{f^{\frac{1}{3}}\ K^{\frac{1}{3}}} \qquad (1)$$

This factorial six-element expression requires a double slide instrument (Rule I.), and there is a factor scale for each slide edge. The shaft diameter S is the dependent and the L.P. cylinder diameter D is chosen as the independent variable.

The primary arrangement of scales is shown in Fig. 30. The scale of the function $K = \left(2 + \frac{D^2}{d^2}\right) = (2 + R)$ is placed on the lower edge of the lower slide and is utilised both as a K and an R scale. This and the f, P and C scales, arranged as shown, are all direct (Rule II.). Before the solution can be mechanically performed it is necessary first to determine the cylinder ratio $R = \frac{D^2}{d^2}$. In the solution of this equation a single slide only is necessary (Rule I.), and with D as independent variable and R as dependent variable, the latter scale (direct) should be placed on the lower (fixed) edge of the upper slide. To avoid unnecessary duplication of scales, however, the scales are arranged for a solution of this equation in the form $d = \frac{D}{R^{\frac{1}{2}}}$ (2). The direct R scale (half the dimensions of the D and d scales, Rule III.), is placed on the lower edge of the lower slide, and the dependent variable d scale, direct on the lower (fixed) edge of the upper slide, the combination being linked by the index line A. In this case since there is no absolute constant the adjustment of the primary arrangement of scales to the final dotted positions is a purely mechanical one. The unit of the base or S scale is taken as 3 in. so that the unit for the C, f, and P scales becomes 1 in., while that for the D and d scales becomes 2 in This choice enables the arrangement to be easily and quickly drawn. The adjustment is carried out as follows :

The K scale and primary index line A are shifted distance a to the right (Rule V.) till K

* Previous articles appeared in Vol. 16, pp. 80—85, and Vol. 18, pp. 216—223.

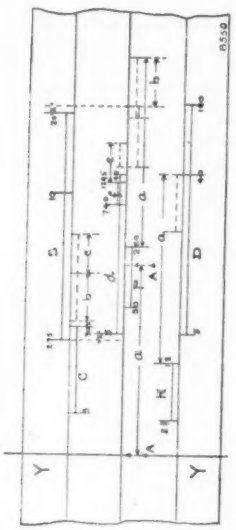

FIG. 30.

= 12 coincides with $D = 40$. This adjustment affects equation (1) as well as equation (2), since this scale is to be used for the R as well as the K factor. To maintain the correct relative positions of the scales for equation (1) the P scale is also shifted distance a to the right (Rule V.). The S and C scales are now shifted distance x to the right (Rule IV.) till $S = 2{\cdot}75$ is in line with $D = 5$. The P scale is next shifted distance b to the left to bring $P = 250$ in line with $S = 20$, and the C scale is shifted distance b to the right (Rule V.). Finally the C and f scales are shifted distance e to the right (Rule V.) till $f = 740$ coincides with $P = 50$. With $D = 40$, $K = 12$ and $P = 50$, $f = 740$ in coincidence, the value of S corresponding to $C = 30$ is 6·453. This settles the exact position of the C scale on the finished instrument, Fig. 31.

Similarly, with $D = 40$, and $R = 12$ in coincidence the corresponding value of d (when the upper slide is "in") is 11·56, and the index line A is therefore drawn against this value. When the engine has two L.P. cylinders each D_1 inches diameter, then the diameter of the equivalent single L.P. cylinder is $D = \sqrt{2}\,D_1$. If an index line B be drawn against the D_1 value on the L.P. diameter scale another index line C distant 1·414 from it to the right, will coincide with the corresponding D value. The index line B has been arbitrarily drawn coincident

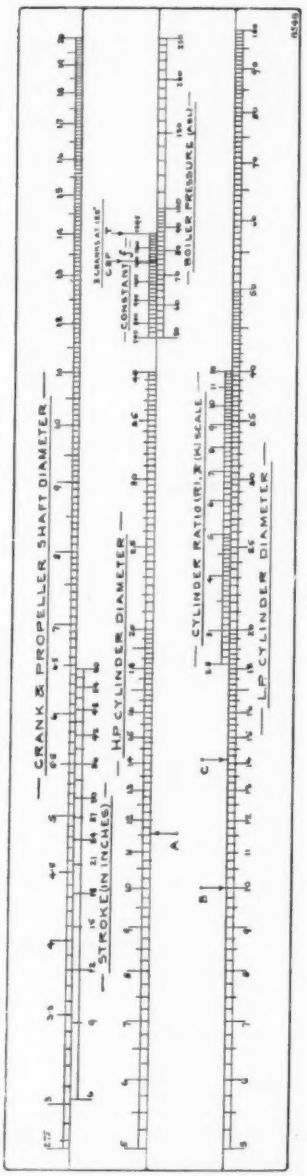
— CRANK & PROPELLER SHAFT DIAMETER —
— STROKE (IN INCHES) —
— HP CYLINDER DIAMETER —
— CONSTANT —
— BOILER PRESSURE (LBS.) —
— CYLINDER RATIO (R) & (K) SCALE —
— LP CYLINDER DIAMETER —

FIG. 31.

with $D_1 = 10$, and the index line C is therefore drawn coincident with $D = 14{\cdot}14$. The range of values of the constant f has been scaled in accordance with the Board of Trade limits, so that the scale can be applied to any particular case, when the f value is known from the tables. The case of the three-crank triple engine with cranks at 120 degs. is, however, the one most frequently dealt with, and the f values for this have been specially marked as index lines, in order to save reference to the tables. The letters "C and P" denote crank and propeller, and "T" tunnel shafting. For the finished instrument the base scale unit chosen is three times that of the upper scale of a 10-in. slide rule, so that this is the only scale which has to be "constructed." The C, f, and P scales are taken from the upper and the D and d scales from the lower scales of the rule. For convenience in reading as in the case of the horse power calculator the C scale is figured with stroke values. The application of this calculator for the determination of shaft diameters involves the preliminary determination of R and K. When K is known the solution becomes "direct," with one setting of the slides. The rule of operation for these two steps may be stated thus :—

(1) *To Determine the Cylinder Ratio R and Factor K.*

If there are two L.P. cylinders first place index line B against the small L.P. diameter and read the "single cylinder" L.P. diameter against index line C.

Bring the slides to the "in" position, then place index line A against the H.P. diameter and read the cylinder ratio R against the (single) L.P. diameter.

Add 2 to R and thus obtain the value of K.

(2) *To Determine the Shaft Diameter.*

Place the K value against the L.P. diameter and the f value against the boiler pressure, and read the shaft diameter against the stroke.

(*To be concluded.*)

Hollow Reinforced Concrete Poles and Pipes.

A process for manufacturing hollow poles and pipes of reinforced concrete has been introduced into this country by Messrs. Siegwart, Ltd., of 1, Great Chapel Street, Westminster. It is the invention of Mr. Hans Siegwart, of Lucerne, Switzerland, inventor of a system of reinforced concrete fire-resisting floor construction made up of hollow tubular beams laid side by side. The principle of the invention is different from the customary method of manufacturing concrete, namely, by casting it in a mould and allowing it to harden therein. The material is used in a plastic way very much like clay, paper pulp, or metal, for by the process of wrapping the concrete round a core no mouldsare required to give it shape and form.

Poles and pipes, which it is the purpose of this invention to manufacture, are made in a machine which has been installed at the works of Messrs. W. Cubitt & Co., at 260, Gray's Inn Road, W.C.

Before dealing with it in detail, and the method of manufacture, we may refer to the general subject of the use of reinforced concrete for the manufacture of such articles as poles and pipes.

The extension of the uses of concrete in the last few years has been remarkable, and perhaps nothing is more striking than its use for such purposes as the manufacture of poles of great height and pipes to withstand great pressure. With the Siegwart process of manufacture we arrive at a stage where iron is largely done without, with resultant economy and efficiency.

Firstly, as regards reinforced concrete poles, their construction has been attempted for some years. The supports for overhead electrical transmission lines are costly, and also must provide every security. At first timber poles were adopted, and they are extensively used to-day, their first cost being much less than iron poles, though their life is comparatively short. A steel or iron pole, though expensive in first cost, proves an economical proposition, however, from its much longer life, and it has received much favour and been extensively adopted as a better and cheaper solution. If of tubular form it is constructed of cast-iron, but the latest type, built of steel in lattice form, is used for high poles. To keep an iron pole efficient, however, it must be periodically painted, and the cost of upkeep is considerable.

The difficulty in constructing a reinforced

concrete pole was to render it light in weight, which it must be to be economical as regards material and transport, and also to manufacture it cheaply. There is no particular difficulty in casting a reinforced concrete pole if it is solid, but when the endeavour is made to manufacture a hollow pole difficulties stand in the way. Short lengths of poles or pipes have been cast between an inner core and an outer casing of metal, but it is difficult to perform even then, especially when reinforcements are introduced into the narrow space between these two sheetings. The difficulty becomes overwhelming when a long hollow pole is to be cast. Consequently, the inner core had to be left within and the weight had also to be considerably increased beyond what was necessary. The embedded wooden core was liable to swell and injure the concrete, and such a process of manufacture was by no means economical. The first cost of such poles was greater than that of iron poles, so that their use was only experimental except for high power transmission lines, for which solid reinforced concrete poles have been found of practical service, there being several such lines in existence.

For ordinary work, reinforced concrete, though it has the great advantages of enabling poles of great height to be constructed, that are very durable and require no expense in the way of upkeep, has not been possible of adoption. The Siegwart process, however, has overcome many of the difficulties, and enables reinforced concrete poles to be constructed at a price which is less than the first cost of iron poles.

Poles for carrying overhead wires have to sustain stresses induced by the suspended wires and wind pressure. Where poles are required for long distance transmission, the importance of adequate security is very great, for the execution of repairs over a wide area is troublesome and costly. For such purposes the reinforced concrete pole offers advantages which place it far ahead of any other means of conveying power.

As regards reinforced concrete pipes, these have been constructed for many years on a large scale. Reinforced concrete can be applied to the construction of water mains, aqueducts and sewers, but difficulties are entailed in moulding a pipe, especially when of small diameter. We have referred above to the difficulty of concreting within a narrow space left between an inner core and an outer sheeting, especially when hampered by the reinforcements placed therein. To tamp the concrete from one end is difficult, and though a very wet mixture of sand and cement is used and poured into the moulds, the manufacture entails difficulties which render the cost of such pipes considerable, though the fact that such pipes have been extensively used abroad, and have even been employed in this country, proves that the ordinary method of manufacture will compete with iron and large earthenware pipes. The advantages of reinforced concrete in the way of durability, for the concrete thoroughly protects the embedded metal against the corrosion, are obvious, but the Siegwart process of manufacture has given additional arguments in favour of reinforced concrete pipes, apart from the economy which is claimed to be effected over the other methods of manufacture. There is, for instance, a saving in the cost of jointing by reason of the greater length of the pipes, these being as long as 20 ft., or twice the length of iron pipes, and four times the length of plain concrete or earthenware pipes, and also a saving in the other expenses of laying in regard to the cutting of the trenches, for the width of the latter can be reduced to a minimum, except at the point where the joint has to be made. Also, the comparatively small number of joints reduces trouble likely to be caused by expansion and contraction due to temperature changes, and so increases the reliability of the pipe line.

The pipes can be constructed to withstand very great pressures. In the case of the larger pipes, which are made up to 2 ft. in diameter, the strength is, if necessary, as much as six atmospheres, while the smaller pipes are made to withstand an interior pressure of twelve atmospheres. A reinforced concrete pipe naturally withstands external pressure, and, if necessary, can be specially reinforced for this purpose. It has considerable resistance against fracture during transport or by shocks caused by street traffic, being of small weight owing to the thinness of the walls, which varies from $\frac{3}{4}$ in. to 2 in. Furthermore, such pipes can be manufactured at the place where required for use, so that the cost of transport, such as would be entailed in bringing either earthenware or iron pipes from a distance, is eliminated.

The process can also be applied to the construction of hollow reinforced concrete piles, for which there is considerable demand.

We may now proceed to the description of the process of manufacture. Fig. 1 gives the general arrangement of the machine for manufacturing Siegwart poles and pipes, as it has been erected at the works of Messrs. W. Cubitt & Co. This view shows how the machine is placed, resting in an open

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concrete pit sunk in the ground, with a track on either side, upon which trestles can be run, and a stage over the machine carrying the concrete mixer which discharges into a receptacle below on the machine itself. This mixer has paddle wheels which rotate in an open box that can be tipped over to discharge its contents into the hopper below; these paddles thoroughly churn up the ingredients.

The concrete used in the manufacture of poles and pipes is made of clean screened Thames grit, which mostly consists of sand, with occasionally small stones not larger than ½ in. maximum diameter, proportioned 3 to 1 of Portland cement. The concrete is mixed very dry, so that it only feels moist, and does not even stick together when pressed in the hand. It coheres in the manufacture by reason of the great pressure which is applied to it.

The concrete, discharged from the mixer into the hopper, falls from the latter into a sheet metal drum, which is clearly seen standing at the back of the machine in Fig. 2. This drum holds a considerable quantity of concrete, namely, about eight cubic feet, which is sufficient as a rule to make one pole or pipe. It is important in the manufacture that the concrete should be fed regularly and continuously, and this drum is arranged to do this; it slides up and down a sort of oblong box or shoot, which is so arranged that the surface of the concrete within the drum is always level with the top of this shoot. The rate at which this drum rises can be regulated so that the quantity of concrete discharged is greater or less according to the thickness of the layer of concrete which is to be applied to the core.

The first machines that were built by Mr. Siegwart travelled along a track, while the pole remained stationary as regards longitudinal movement. This, the first machine to be erected in this country, is the first to be built to remain stationary, while the core is moved longitudinally (as well as rotating on the trestles before referred to). By moving the core instead of the machine, difficulties of feeding the latter with concrete are overcome, and many minor advantages obtained.

The hollow space in the interior of the poles or pipes is formed by means of the core of sheet iron, which is removed after the concrete has been applied to it, the process of removal being made possible by an arrangement whereby the diameter and circumference of the core is reduced by an internal mechanism. Gauge rings are arranged on the core at suitable distances from each other, and steel rods or wires of small section are passed through holes in these gauge rings, and arranged to lie longitudinally upon it. In the pipes these wires or rods are not stretched, for the operation of applying the concrete thereto draws them taut, but in the poles the wires are stretched tightly by means of hooks that are screwed up at the ends of the core. Upon the track two trestles are placed, as shown in Fig. 1, and the core is mounted between them so as to be capable of rotation therein. The trestles have toothed pinion wheels, which engage with a rack on the track, and are drawn gradually along in the direction of the machine, by means of a wire rope that is wound up by being geared, so that the core passes through it at the right rate of progression.

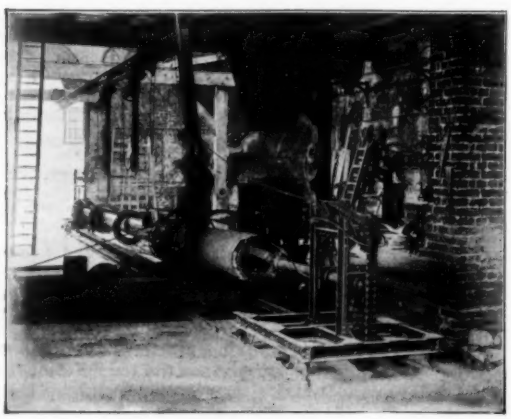

FIG. 1.—GENERAL ARRANGEMENT OF THE MACHINE FOR MAKING HOLLOW REINFORCED CONCRETE POLES AND PIPES.

The concrete is applied to the core by means of rotation. The concrete from the drum falls down the shoot above referred to, upon a conveyer band or belt made of strong steel wire tightly plaited that takes one wrap round the core, and is given its motion by passing over two wheels. One of these wheels (that at the front of the machine) is mounted in a sliding carriage that receives preliminary adjustment by means of a long screw turned by a spoked hand-wheel at the back of the machine. By means of the two heavily weighted levers, the sliding carriage applies a

pressure of about 5,000 lbs. to the conveyer-belt, so that the concrete is wrapped upon the core under this pressure. Upon the conveyer band is a chain-like device, which affords a grip for a band of strong cloth webbing about 4 ins. in width, laid on top of all. The concrete falls upon this webbing, and the webbing and the concrete are wrapped round the core in a continuous spiral, so that the pipe or pole issues with a bandage round it, as shown in Fig. 2. The edges of the webbing just overlap so that the concrete layer thereunder and the webbing are continuous, the latter so preventing the concrete dropping from the core. The pressure on the conveyer belt draws the longitudinal wire or rod reinforcements closer together. The guide rings holding the longitudinals in position are engaged by a wheel attachment, so that they slide along the rods as the core gradually passes towards and through the machine.

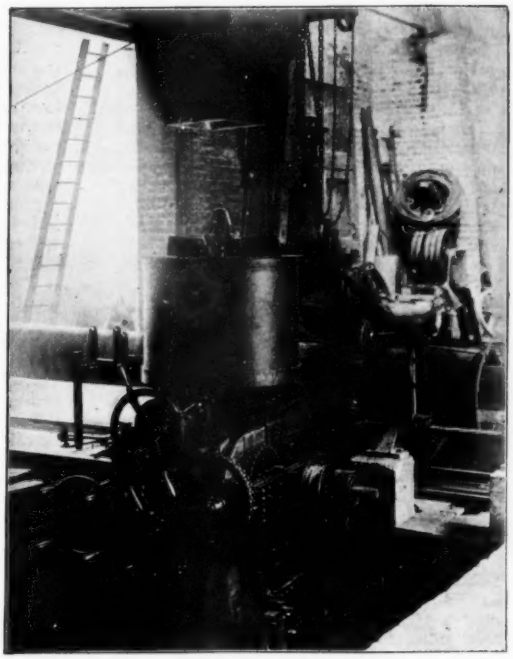

FIG. 2.—BACK VIEW OF MACHINE.

Immediately the webbing and concrete issues beyond the conveyer belt, wire or wires, as close together as may be desired, are fed by a spool on the attachment somewhat resembling an elevator. The webbing is drawn up over a bar above this spool of wire, so that the wires for the spiral binding may be fed upon and into the concrete. A rod fastened to this elevator attachment keeps it rigid, and the rotation of the core draws the wire or wires from the spool so hard against the layer of concrete that they penetrate into it for some distance. If these spiral wires are of large section, there is insufficient power developed to draw them into the layer of compressed concrete, therefore another device is brought into action, consisting of a wheel with spikes thereon that cut grooves in the concrete as the core rotates, into which the wires may penetrate. The rotating core draws the band of webbing upon the surface of the concrete again, and a pressure roller on the end of a long spindle, which is screwed forward by hand, works on a sheet iron ring, and presses this webbing and the concrete hard against the core, in order to give it a final finish and hardness. The thickness of the layer is, by the great pressure given by this roller, slightly reduced, and the reduction in diameter and circumference thereby means that the quantity of webbing that was originally fed into the machine is now too long, but the slack is taken up by the elevator attachment above referred to, which is suspended by means of a wire rope running over a pulley on the platform above having a weight hung from the end thereof, this arrangement enabling the elevator to gradually rise as the amount of slack in the webbing increases.

The electric motor that works the machine is mounted on the bottom frame, and the driving is by means of a worm wheel and several chain wheels. The machine can be adjusted to the necessary angle to the core if tapered, such as in the case of a post.

As soon as the core has been drawn through the machine completely wrapped with the spiral binding, it is picked up by a travelling crane overhead and slung on one side to enable the concrete to harden and mature. To ensure it gaining maximum hardness it is constantly wetted.

The interior sheet metal core can be removed by being reduced in diameter by the screw attachment within after about

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twelve hours, and the bandage of webbing may be removed after six day's hardening. This webbing leaves a few small markings on the pole which are no detriment for a pole erected in a place where appearances are not of great importance, such as in the country. To complete a pole, all that requires to be done after it comes from the machine is merely to fix a stopper in the top and make a square necking or blocking for fixing the cross-arms that carry the insulators and the electric wires. The former is cast in a mould and dropped into the top of the post; the latter is moulded by hand. Where a more finished appearance is destined, the poles are given a wash of cement grout or rendering of cement and sand.

Fig. 3 is a diagram of the arrangement of the reinforcement and details of the construction of a typical pole. It will be seen that the reinforcing skeleton consists of longitudinal rods tied together by a wire or wires wound spirally thereon. It is important in such tubular construction to have the reinforcements correctly disposed, and the process ensures every control over their position and accurate placing.

The thickness of the concrete varies from 1 to 2 ins. in the poles, but the pipes vary from ¾ in. to 2 ins. in thickness. A Siegwart pipe that has been tested successfully resisted an internal hydraulic pressure of 285 lbs. per sq. in. The pipes have a special shaped joint for resisting pressure. Bitumen is filled in in the hollow spaces of the joint, and a short piece of pipe is passed over the joint and connected to the pipe with bitumen. It was such a joint that withstood the pressure of 285 lbs. per sq. in. For ordinary pipes not called upon to sustain pressure, the jointing is by means of collars of reinforced concrete or sockets on the pipes.

As regards the calculations for the size of reinforcements, thickness of shell and general proportions of the poles, the theory which is adopted is similar to that employed for the strength of chimneys, and the stresses that have to be sustained are tension on the one side and compression on the other. In chimney designing, however, it is customary to ignore the compressive resistance afforded by the reinforcement, but with a thin shell, such as is possessed by the Siegwart pole, this has to be taken into account. The problem may also be treated from the point of view of a hollow tubular beam, or rather a cantilever. The stresses that come upon the pole are not only the tension of the electric wires, but the wind pressure also.

FIG. 3.—DIAGRAM SHOWING DETAILS OF THE REINFORCEMENT.

The longitudinal reinforcements are made each in one length continuous from top to bottom as there is tension induced in them, but in the pipe construction referred to below, several rods, shorter than the total length of pipe, are often used.

The size and disposit on of the reinforcements in pipes is determined by a theory that has been thoroughly worked out. The bursting pressure from the inside is required to be resisted solely by the hoop tension of the spiral reinforcements, while the longitudinal wires resist the bending moment induced in the concrete shell between each spiral, while at the same time serving to strengthen the pipe as a beam to resist the forces to which it is subjected in transport and lifting and placing in the trenches and in lying on an irregular bed. If the pipes have to withstand pressure from without, the calculations are based on the assumption that each section of a pipe is an eccentrically loaded pillar or post. The thickness of the concrete bears a direct relation to the pressure in this latter case, but with pipes to withstand internal pressure the thickness of the shell is determined not so much by its strength as by its permeability. The thickness, therefore, of the concrete layer is standardised for various sizes of pipes and pressures solely from practical consideration as regards the impermeability of the concrete, shocks in transport, putting in place, &c. The predetermined thickness of the concrete shell enters into the calculation for the sizes of the longitudinal reinforcements, though it does not affect the determination of the size and disposition of the spiral reinforcement.

Hollow piles constructed by a similar process can be made up to the standard length of 39 ft., which is adopted for the longest poles. The piles usually have their sides parallel, *i.e.*, they are of the same diameter throughout, but sometimes they are tapered. The system of reinforcing a pile with spiral wires is now generally looked upon as the most efficient form of reinforcement, but it is difficult to manufacture such a pile to secure thorough homogeneity, and a solid pile spirally reinforced is not only expensive in manufacture, but also in handling and driving by means of its great weight. A pile is subjected to stresses,

induced by the shattering effects of the blows in the driving, while it has to sustain the ultimate load as a column, and where driven in such situation as in piers or jetties may be subjected to the impact of a ship riding against it, when it has to act as a beam built in at both ends, the one end being fixed by the ground in which it is driven, and the other end by the decking.

Columns for ordinary building work can be made advantageously by the Siegwart process.

The Evolution and Methods of Manufacture of Spur-Gearing.

ORIGIN OF SPUR-GEARING.

THE best authorities on the subject are unable to say when spur-gearing was first introduced, but it has certainly been used for an exceedingly long period. The following is a suggestion put forward by the author as to its origin. Fig. 1 shows two trunks of trees lying on the ground at right angles to each other, the stumps of the branches of one being interlocked with those of the other. When the branch is pressed down it causes the trunk to roll slightly on the ground, and the interlocked branches transmit the motion to the other trunk. Fig. 2 is a sketch which suggests the first piece of work made in the evolution of spur-gearing.

The first practical applications of spur-gearing to machinery were undoubtedly in connection with windmills and water-wheels for moving stones to grind corn. Fig. 3 is taken from an ancient drawing of a wind-mill, in which the wheels and axles were made entirely of hard wood. The arms were fixed, high above the ground, to a horizontal shaft, which transmits the motion through a pair of wheels to a vertical shaft. This vertical shaft drives the upper stone, and the weight of the stone, combined with the circular motion, crushes and grinds the corn.

From the earliest times waterfalls must have impressed the mind of man with the idea of utilising their force, and the outcome of this was the water-wheel. Spur-wheels were the only means of conveying motion to the stones, belts and chains being unknown at that period.

For a great number of years all gearing of this kind was made of wood. Fig. 4 is taken from an old built-up wheel entirely made of hard wood.

In the old days nearly all millers built their own mills, and kept them in repair. Later on, some of these men found it to their advantage to give up milling, and to devote their whole time to putting up mills and doing the necessary repairs, and these specialists were called millwrights.

The wooden spurs, from continual use, wore very badly, and the millwright put in spurs with larger wearing faces, which gradually shaped each other, becoming hollow in the flank and rounded towards the points. When broken spurs were replaced, the curved shape was given to them, so that they would work smoothly with the others, and when new wheels were put in they were fitted throughout with shaped spurs. This was the origin of the epicycloidal form of tooth. An old cider-mill in Herefordshire, which must be considerably more than a century old, has wheels of oak in which the spurs have been roughly shaped to an involute form. Iron spurs were once tried in place of the wooden spurs, but after a little work they became loose. The noise that they made was very objectionable, and eventually a return was made to wooden spurs.

For heavy work the millwright introduced an iron wheel with spurs on the rim, cast in one piece. A wooden pattern of the whole wheel was made, with the teeth shaped and spaced round the circumference as accurately as possible. Then, after the casting was made, the millwright had to pitch and trim every tooth with hammer and chisel, finishing them with a file or piece of grinding-stone. To work with this wheel the millwright devised an iron wheel which, instead of having teeth cast on its periphery, had holes or mortices cored in the rim at equal distances apart. Into these mortices hard wooden teeth or cogs were fixed and the projecting parts were divided and shaped to gear smoothly with the cast-iron teeth. Many of these mortice-wheels are working at the present day, and are considered most suitable for their purpose. As time went on, the wooden cogs gave trouble; for, owing to shrinkage and the great pressures, they became loose. Eventually another iron wheel with cast teeth took the place of the mortice-wheel.

It was the common practice to have what was known as a hunting tooth in the large wheel—that is, one tooth more or less than an exact ratio between the wheel and pinion. The object was to obtain a complete interchange of all the teeth, so that they wore evenly and smoothly.

WHEEL-CUTTING MACHINERY.

One of the first known makers of wheel-cutting machines was J. G. Bodmer, a Swiss engineer, whose works were in Manchester. The teeth of wheels cut by this machine were cut with a formed disc-cutter. Fig. 6 shows one of its segments which were apparently held together by a collar on each side, and fixed rigidly by a nut on the mandrel. The teeth of this segment were cut by a milling cutter guided by a former, and the top portions were filed after milling. Cutters like this composed of segments were novelties, but the style of the teeth, copied from the rose bit, was common. If these cutters were sharpened, the thickness of the teeth would be slightly reduced, and the

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FIG. 1.—SUGGESTED ORIGIN OF SPUR-GEARING.

parallel portion which cuts the part below the pitch line would cut too narrow a space. Hence the cutters were not sharpened, and their life was very short.

Fig. 7 is from a photograph of a wheel-cutting machine made between the years 1824 and 1834. A vertical frame carries at the back a dividing-wheel and worm, and a set of change-wheels is provided to give the divisions for any number of teeth required. The blank is carried on the front of the frame on a horizontal spindle, and the cutter is fed in horizontally by hand. An arrangement is also shown whereby the cutter-head can be tilted for cutting bevel-wheels. The method of driving the cutter was evidently by a gut-band passing over two jockey-pulleys, and as no gearing was used to help the band, only small pitches could be cut. In the middle of the cutter-mandrel is seen a hole for a single-pointed cutting-tool or fly-cutter. The machine has all the essential points of an up-to-date Gould and Eberhardt machine, with the exception of the automatic feed and the end support for the mandrel. This machine, together with others of the same type, but of larger capacities, is still working at an engineering works in Salford. The design is generally credited to Richard Roberts, a partner in the firm of Messrs. Sharp, Roberts & Co., of Manchester, but it is thought by others to be the

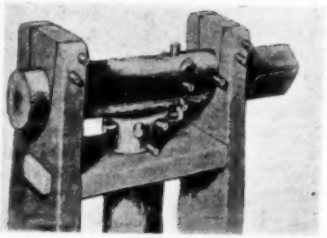

FIG. 2.—PROBABLE EARLY FORM OF GEARING.

work of J. G. Bodmer. After Bodmer had given up his works at Manchester he settled at Bolton, where he made another wheel-cutting machine. This machine has a work-table 6 ft. in diameter. connected to a worm-wheel 5 ft. 4 in. in diameter, having 360 teeth of $\frac{9}{16}$ in. pitch. The accuracy of this worm-wheel at the present time leaves nothing to be desired. The cutter-head, carried on a pillar, is moved on the horizontal bed according to the size of the wheel to be cut, and there was also an arrangement, not now available, whereby the cutter-head could be swivelled to any angle, for cutting bevel-wheels.

Involute Teeth Generated. — In 1835, Joseph Whitworth (afterwards Sir Joseph) was granted a patent for a wheel-cutting machine. From his specification it will be seen that the wheel-blank being cut was a worm-wheel geared to the cutter by a train of wheels in an exact ratio, and in such a manner that no slip could take place. In all probability this was the first machine to generate involute teeth. Fig. 8 represents a machine made by Joseph Whitworth between the years 1834 and 1844, capable of cutting spur and bevel-wheels. The main

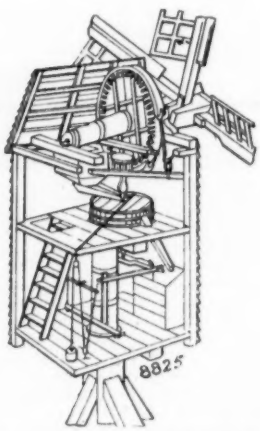

FIG. 3.—WINDMILL WITH WOODEN GEAR.

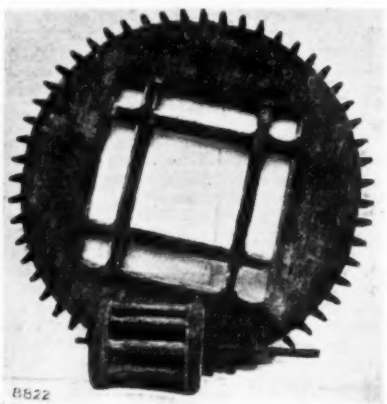

FIG. 4.—WHEEL AND PINION OF HARD WOOD.

drive was by a gut-band and a pair of spur-wheels. The dividing was done by a large plate with holes drilled in circles, and the cutter was fed by hand.

Machine for Milling Formed Cutters.—About the year 1851 Messrs. Shepherd, Hill and Spink made their first machine for cutting wheels. Fig. 9 is taken from a photograph of one of their earliest machines. The bed is long and narrow. The cutter bracket can be swivelled at its base for cutting bevel-wheels, and it is set to zero for cutting spur-wheels. The drive is by an endless rope and a pair of spur-wheels to the cutter-mandrel, and there is a self-acting feed. When one tooth is finished, the blank must be turned round by hand to the next, and the correct division is obtained by means of change-wheels. The dividing head and work mandrel are moved along the bed by a horizontal screw to suit the diameter of the wheel being cut.

In 1856, Christian Schiele, of Oldham, took out a patent for a thread milling machine which was also capable of cutting the teeth of wheels. From his specification it is seen that the blank to be cut is geared up with worm-cutter, and when this cutter is efficiently guided the teeth will be perpendicular, as in an ordinary spur-wheel. This marks a step in advance of Sir Joseph Whitworth's device already referred to, for Sir Joseph Whitworth's machine was only for cutting such wheels as have their teeth oblique to the axis. In Schiele's patent is, in fact, the germ of the modern gear-hobbing machine, but the author has been unable to find any trace of such a machine having been made from this specification.

Fig. 10 is a photograph from an old drawing of the first gear-shaping machine, designed by Mr. Potts, a member of the celebrated clock-making firm. This machine appears to be the first attempt at planing or shaping bevel and spur gear-wheels from a large former-plate. A gold medal was awarded for this machine at the Paris Exhibition of 1867. Fig. 11 is taken from a book which illustrates all the important wheel-cutting machines exhibited at the Paris Exhibition of 1867, and its main features can easily be understood from the figure.

MACHINE RELIEVED CUTTERS.

It has already been seen that the early formed milling cutters were a very expensive item, owing to the fact that it was impossible to sharpen them without spoiling them. This gradually brought about the introduction of a new kind of cutter, now known as the relieved or backed-off cutter, which could be easily sharpened without altering its form. These relieved cutters have about one-fifth the number of teeth of one of the old-formed cutters of the same size. The teeth are cut through from side to side, like a saw, for the whole length of the formed part, and the cutting face is radial. The backing-off to the teeth was done on a slotting or shaping machine with a formed tool.

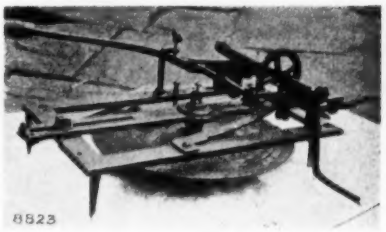

FIG. 5.—OLD WHEEL CUTTING MACHINE AS USED BY CLOCK-MAKERS.

At this time the great majority of spur-wheel teeth for engineers were of the epicycloidal form. These teeth were difficult to cut even with a relieved milling cutter, owing to the flanks of the teeth being nearly parallel. After a little use the cutters jammed in the work and so caused endless trouble. Yet with all this the milling cutter had proved very useful, and it was not long before an alteration in the shape of spur-teeth was made for small wheels.

INVOLUTE CUTTERS.

About the year 1874 Messrs. Brown & Sharpe, U.S.A., brought out complete sets of machine relieved involute gear cutters. The shape of the cutters was based upon a system first introduced by Professor Willis, of Cambridge, in 1836. In American practice involute teeth are invariably employed, but in this country, whilst all teeth of small pitch are involute, epicycloidal teeth are often used for the larger pitches. The great advantage of involute teeth is that the distance apart of the centres can be varied without impairing the efficiency of the gearing, and the angular velocity ratio remains constant. With epicycloidal teeth, on the other

FIG. 6.—CUTTER BY BODMER.

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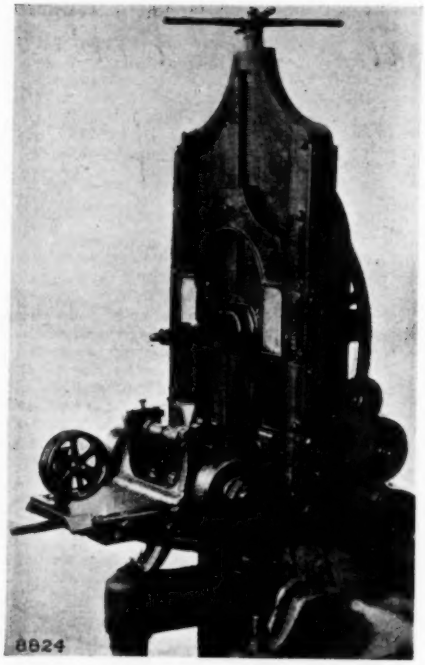

FIG. 7.—WHEEL CUTTING MACHINE ABOUT 1824-34.

hand, the wheels must be kept exactly in gear on their correct centres or the teeth will wear very badly. With epicycloidal teeth the outward thrust is less than with involute teeth.

DOUBLE HELICAL SPUR-GEARING.

About the year 1880 Messrs. P. R. Jackson & Co. brought out the double-helical spur-gearing, the object being to bring the teeth into gear more gradually, thereby reducing the noise. The true action of the teeth can be best understood from the following explanation. Take two short screws, one right and the other left hand, both of the same diameter and pitch. If one thread is rolled into the other the screws are single-helical wheels. If the driven wheel is retarded the screws tend to move endwise in the direction of their axes and in opposite directions. To balance this end pressure, add another pair of screws similar to the first pair, fixing a right-hand and left-hand screw together on each spindle. The result is a double-helical wheel. It will be readily seen that the resistance has a tendency to separate the pair of screws on one spindle, while it tends to press the pair on the other spindle closer together. In heavy gearing the bursting and compressing forces due to the wedge action would become very great, but they are actually reduced by using multiple threads. This alters the angle of the threads, so that the threads are more nearly parallel to the axis of the wheel and the ends of the threads have more the appearance of ordinary spur teeth.

Another very practical way of explaining this system is to make forty-one metal discs about $\frac{1}{16}$ in. thick. Bore and turn them and then, stringing them on a mandrel, clamp them together and cut teeth on them just as if they were one solid blank. Then slack the nut of the mandrel, and, beginning from the outside, turn each disc so that the teeth are slightly in advance of those on the one before it. When the twenty-first or middle disc has been reached the other discs must be turned in the reverse direction, so that the teeth are now slightly behind those on the preceding discs. Great care must be taken to turn each disc through exactly the same amount. It will now be seen that one-half of the teeth form a stepped right-hand helix and the other half a stepped left-hand helix, and the forty-one discs clamped together in this position form a stepped double-helical wheel. If the edges of the teeth in a stepped wheel were bevelled off they would form correct double-helical teeth, and the action would be more gradual. Stepped wheels and racks were made in many cases where smooth working was required, and many

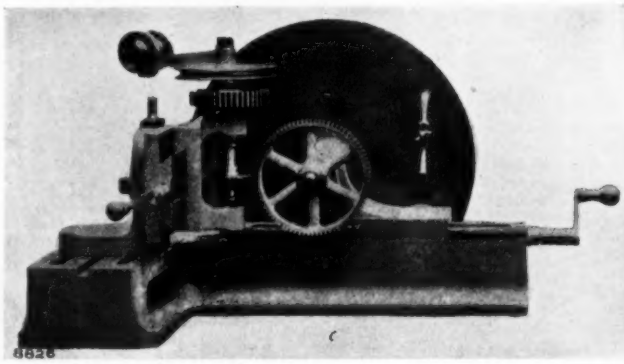

FIG. 8.—WHEEL CUTTING MACHINE BY WHITWORTH; 1833-44.

examples are still to be found in old planing machines. Correct double-helical gearing when made by experienced firms is very silent in action, and for heavy duty nothing has yet replaced it either in regard to strength, silence, or cost. The largest gears in the world have been made on this system by Messrs. P. R. Jackson's moulding machine, capable of moulding wheels up to 30 ft. in diameter by 36 in. width of face and 9 in. pitch. The form of tooth is epicycloidal. The wooden pattern teeth are cut on a special device attached to the machine.

SPUR GEAR PLANING AND SHAPING MACHINE.

Messrs. Gleason, of Rochester, U.S.A., have made machines for planing the teeth of spur gears up to 24 ft. diameter by 24 in. face and 6 in. pitch. A former plate is used as in Potts' original system. The large pitch gears usually cut on these machines are generally cast with teeth sufficiently thick to allow for machining. This reduces the weight of the castings, saves the time otherwise spent in stocking out the teeth, and the teeth are freer from sponginess owing to there being less metal in the rim.

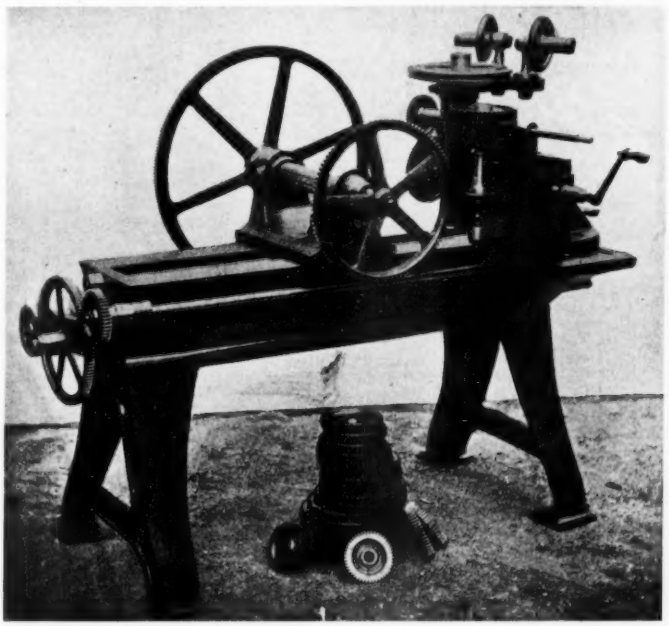

FIG. 9.—WHEEL CUTTING MACHINE; 1851.

Another kind of spur-gear generating machine is the "Fellows" gear-shaper. Its action is similar to that of a slotting machine, but instead of the ordinary slotting tool it carries a twelve-toothed pinion for its cutter. The teeth are of true involute form, hardened and ground up all over. The spindle carried in the reciprocating vertical slide is geared up by spur-wheels and change wheels to the work table. The cutter is fed into the blank to the full depth of the teeth, and then, while the cutter is continuously reciprocating, the blank and cutter slowly revolve together at the exact ratio between the number of teeth in the cutter and the blank being cut. One revolution of the blank completes the operation. Only one cutter is required for all wheels of the same pitch, and the machine is equally suitable for spur-wheels and internal wheels.

Other steps in the development of wheel-cutting machinery are exemplified in the "Brainard," the "Sellers," the "Thompson & Fitton," Birch's, Gibson's (worm and bevel wheel cutter), Smith and Coventry's and the "Oerlikon" machines. Each of the methods above mentioned or described forms a link in the development of wheel-cutting machinery. Sometimes the process has been by some sort of planing action, the tool being guided by a former; sometimes the process has been done by shaping tools, and at other times by milling cutters in various ways.

HOBBING MACHINES.

In all machines that have been described so far, one tooth must be finished before the next one is begun, but in the gear-hobbing machine the teeth are generated in circles, and they are all begun and finished practically simultaneously. The cutter or hob consists of a cylinder having wound round it a single right-hand thread. The thread has straight sides inclined to each other at an angle of 30 degrees. This thread is divided into teeth by spiral slots cut through it at right angles to the thread, and the tops, sides

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and bottoms of the teeth are backed off. The cutter is fed down through the blank, and the blank and cutter are geared together by change wheels, so that they revolve at the correct ratio between the number of teeth to be cut and the thread of the hob. That is to say, for one revolution of the blank the hob must make as

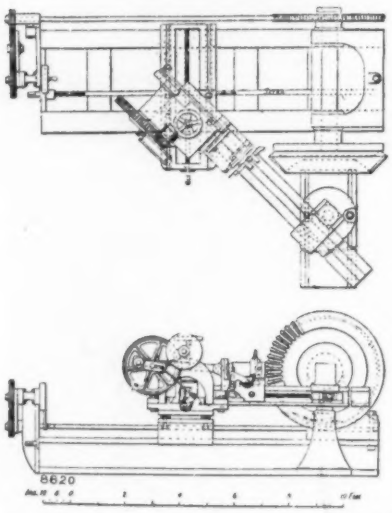

FIG. 10.—BEVEL AND SPUR-WHEEL SHAPING MACHINE (FOTTS) MADE BY SHEPHERD, HILL & CO., LEEDS.

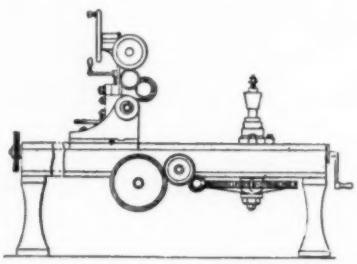

FIG. 11.—GEAR-CUTTING MACHINE, 1867.

many revolutions as there are teeth to be cut. The action is the same as that of an endless rack which is moved along in gear with the wheel that is being cut. It is clear that the pitch line of the rack must move at exactly the same rate as the pitch line of the wheel. All the metal which interferes with the rack teeth is removed. Thus the teeth of the wheel are generated to the true involute form, and only one hob is required for all wheels of the same pitch.

In order to cut a correct spur-tooth, the axis of the hob must be tilted to the angle of spiral of the thread. Otherwise, as the cutter is fed downward, the spaces would be cut too wide It is also necessary that one tooth should be set exactly on the centre line of the machine. This is the tooth which finishes the bottoms of all the teeth in the wheel. If no tooth in the hob is set exactly on the centre line, the wheel teeth will be cut slightly out of upright. The hobbing principle was first foreshadowed by Sir Joseph Whitworth's invention of 1835, and a hobbing machine was actually invented more than fifty years ago by Christian Schiele.

It is probable, however, that one of the first gear-hobbers actually made is a machine that has been working continuously since 1893 in the works of Messrs. George Juenpt & Sons, Crofton Falls, New York. This machine is shown in Fig. 12. A gear-hobbing machine was brought out about 1894 by Messrs. Reinecker, of Chemnitz, Germany. This machine was made to cut spur-wheels, worm wheels, and spiral wheels. In both these machines the gear blank is carried on a horizontal mandrel, and the hobbing cutter is fed horizontally. A later example of the same type is the "Biernatzki." By far the greater number of gear-hobbers are now, however, of the vertical type, that is to say, the wheel blank is held on a vertical mandrel, and the cutter is fed vertically downwards.

The best known is the "Pfauter." These machines are made in many sizes; the largest, capable of hobbing wheels up to 10 ft. in diameter, and one diametral pitch, is shown in Fig. 13. The main drive is from a countershaft and stepped cone pulley in the bed near the ground. From the first driving shaft the motion is taken off to change wheels at the back of the machine and to a vertical shaft, and from this vertical shaft the motion is conveyed to the hobbing cutter by bevel wheels and spurs. The hob bracket can be swivelled completely over, so that the hob can work at any angle. The arrangement for cutting spiral wheels is very ingenious. A differential gear is placed between the change wheels and the worm shaft, which revolves the work table. This differential gear can be set by means of suitable change wheels to advance or retard the worm shaft by the exact amount required. Another set of change wheels is used for the feed.

The first British firm to enter the field with a gear-hobbing machine was Messrs. John Holroyd & Co., of Milnrow.

Messrs. Armstrong & Whitworth make a machine to hob wheels up to 6 ft. in diameter. The special feature of this machine is that instead of the work table sliding on the bed to suit the diameter of the wheel being cut, the vertical column which carries the hob bracket is adjustable on the bed. In Messrs. Wallwork's machine the cutter spindle is driven by

a worm and wheel to give smooth running. The feed is through a gear box giving three changes. The top of the work mandrel is supported by a bracket fixed to two vertical columns carried by the base slide of the work table.

In the machine built by the author's firm for cutting spur and worm wheels, no countershaft is required, and as the driving pulley is fixed on the top of the column, the machine can be put down anywhere in the works and the belt received at any angle. It is also so arranged that a motor can be mounted on the top of the column. When belt-driven there is a light, loose pulley and a heavy flywheel, which is found to be an advantage owing to the intermittent cutting of the hob. The flywheel runs at a constant speed, and a gear box giving four changes of speed is provided, so that a constant torque is always maintained from the belt to the hobbing cutter. The rate of feed can be altered while the machine is running. The feed gear consists of two taper cones and a belt which can be shifted by means of a fork, moved by a screw. To obtain a wide range of feeds the difference given by the cones is multiplied by means of an epicyclic gear, and practically all the strain is taken off the belt. Thus any feed can be given from $\frac{5}{1000}$ to $\frac{120}{1000}$ in. per revolution of the blank being cut. The work mandrel is tied to the top of the vertical column by two cross stay bars to prevent deflection and stiffen the blank whilst being cut. A section through the worm driving the work table is shown in Fig. 14. The machine is very stiffly built, and is intended to cut steel wheels of large pitch.

MANUFACTURE OF HOBS.

The chief trouble of this system of generating gears lies in the manufacture of the hobs. The hob is made out of one solid piece of steel, which is bored and turned and the keyway cut. Then the thread is roughly milled out and also the spiral slots between the teeth. Next the teeth are relieved or backed off in a special lathe, and the lathe tool is carried in a rest which has a multiple motion. For every tooth, the tool is moved in and out by means of a cam, and at the same time it is fed forwards to follow the thread of the hob. During this process an allowance can be made for expansion or contraction anticipated in the hardening of the hob. After the teeth have been relieved, the hob goes into the tempering department. This is the most dreaded part of the process, for the work which has been done so carefully may be spoilt in the fire or in cooling even with the most experienced men. To complete the hob it is necessary to grind out the bore and over the tops of the teeth to true them up. Finally the cutting faces of the teeth are ground back just sufficiently to remove the grinding marks on tops of the teeth.

Even after this lengthy process it is sometimes found that a hob has gone slightly out of pitch in the hardening. Attempts have been made to correct this by grinding

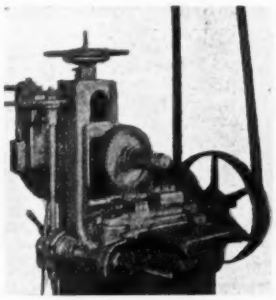

FIG. 12.—GEAR HOBBING MACHINE (JUENPT); 1893.

the side of the hob teeth after hardening. For this purpose a small emery wheel was used in the backing-off machine, but, owing to the small diameter of the emery wheel which had to be employed to pass between the threads, and the great speed required, this has not proved very successful.

The author has brought out a hobbing cutter with inserted blades or racks which are fitted into grooves cut in the body of the hob. These grooves are not cut radially, for in a cross section of the hob the centre lines of the grooves are tangential to a small circle concentric with the periphery of the body. The thread is roughly cut and then the blades are taken out and tempered, and the parts that fit in the body are ground. They are then replaced in the body and the thread is ground up all over, so that any error due to tempering is corrected. The blades are again taken out of the body and turned end for end in the grooves, being replaced so as to keep the continuity of the thread. Owing to the grooves being tangential, this will tilt the blades and so give the necessary clearance or backing-off to the teeth. The blades

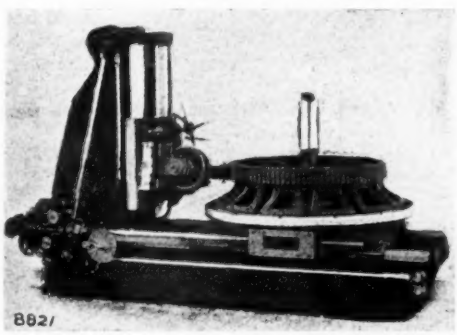

FIG. 13.—GEAR HOBBING MACHINE (PFAUTER).

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are rigidly held in the grooves of the body by long keys. Several sets of blades of different pitches, either diametral or circular, can be used in the same body, and if a tooth gets broken it only means that one blade is spoilt, and this can easily be replaced. It is thought that this method of construction will lend itself particularly to hobs of large pitch, as at present the large solid hobs are very expensive. At the time of writing only two of these hobs have been made, and it is still too early to say how far they have an advantage over solid hobs. The results obtained are, however, sufficiently good to encourage further trials.

UNDERCUTTING OF PINIONS.

One point sometimes urged against the hobbing principle is that, as all the wheels are generated by rolling into a rack, the flanks of pinions must necessarily be undercut. The teeth of pinions could be made stronger by increasing the angle of the sides of the rack teeth, but this has the disadvantage of increasing the angle of obliquity and so throwing a greater outward thrust on the bearings. Nevertheless, the evil effects of this increased angle of obliquity are thought by many to be exaggerated, and Wilfred Lewis recommends the use of involute teeth having an angle of obliquity of 22½ deg.

The author is, however, in favour of retaining the present form of hob having sides inclined to each other at an angle of 30 deg. In the case of wheels of less than thirty teeth, he recommends that the blank should be turned to a rather larger diameter than the correct diameter for the number of teeth required. The cutter is set to the full depth of the tooth just as if the blank were the correct size. The base circle from which the involutes are unwound is not altered by altering the size of the blank, but if the blank is over size we shall get teeth very strong in the roots with short flanks and long addenda. The centres of the wheel and pinion are, however, slightly further apart and the angle of obliquity is increased. Thus with the same hob almost any desired strength can be given to the teeth of a pinion, and all the pinions will gear perfectly with the wheel cut on a correctly-sized blank.

It must be understood that there are limits to the amount of error which can be given to the diameter of the blank, for if the error is too great the teeth will be cut off altogether. As an illustration, take a 24-tooth wheel gearing into a 12-tooth pinion of 2-diametral pitch. The correct centres for these are 9 in. apart, and the angle of obliquity is 15 deg. Now cut twelve teeth on a blank intended for thirteen teeth. The centres will now be 9¼ in. apart and the angle of obliquity is 21 deg. This is rather an extreme case, but a very strong form of tooth can be obtained with a blank sized for 12½ teeth. The longer involute of the pinion teeth causes these wheels to run very smoothly together. Fig. 15 illustrates a series of 12-tooth pinions cut on blanks sized for 11 teeth up to 13 teeth. The third in the series is cut from a blank of the correct diameter.

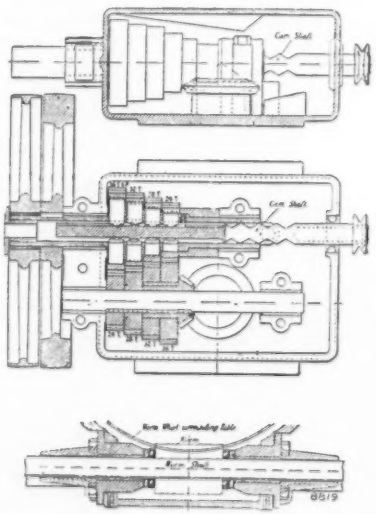


FIG. 14.—CHANGE SPEED GEAR AND DETAILS OF WORM DRIVE FOR TABLE; GEAR HOBBING MACHINE.

DISADVANTAGES OF DISC MILLING CUTTERS.

The introduction of automatic gear-cutting machines cheapened cut wheels to such an extent that they soon came into favour for all high-class work. As has been explained, unless the number of teeth to be cut in the blank correspond to the lowest number stamped on the cutter, the teeth will not be correctly shaped. Moreover, as the cutter gets blunt, the centres of the cutter and work mandrel are forced apart, and the bottoms of the teeth describe a slight scroll. Also as one tooth is finished at a time, the strains of the metal being released locally and the heat generated cause the wheel to be distorted from a true circle.

The extraordinary demands of modern high-speed machinery rendered it necessary to find something still better. In all gear generating machines the teeth, no matter what number there are in the wheel, are developed to the true involute form so long as the tool keeps sharp, and in the gear-hobbing machine which generates the teeth simultaneously nearly all the disadvantages of the disc milling cutter are overcome. Moreover, while the milling cutter has about twelve cutting teeth, in the case of a hob the cutting is done by about thirty teeth. In practice it is found that with a good stiff hobbing machine, from two to three times as

much metal can be removed per hour as with a machine using a disc milling cutter of the same pitch. With the improvements in hobs suggested by the author the troubles caused by the hob going out of pitch in hardening may be eliminated, and wheels cut with such a hob as this probably come as near to perfection as can be obtained on any wheel cutting machines.

DISADVANTAGES OF THE HOBBING PRINCIPLE.

Nevertheless, there are certain disadvantages of the hobbing principle. In the first place, owing to the spiral twist of the blades a section of the blade normal to the axis of the blank is not a perfectly true rack, and in consequence the points of the teeth are very slightly too thick. Secondly, while the blank rotates continuously the cutting is intermittent, and after one tooth of the hob has taken a cut a small piece of metal escapes before the next tooth comes into action. If a hobbed wheel is examined it will be seen that the sides of the teeth show a series of small flats. By increasing the number of teeth in the hob, the flats are made smaller, and if there were an infinite number of teeth in the hob it would generate a smooth curve.

GRINDING WHEELS.

Of recent years there has been a great tendency towards grinding the teeth of the change gears for motor cars. At first the wheels were run in with emery and grease. This was found to take off as much metal from the parts that were correct as from those that were incorrect, and while some wheels ran much better after this treatment others were decidedly worse. However, something in the way of grinding has long been requisite, and about two years ago a machine was made by Messrs. Reinecker on the same principle as the machine used in the "Fellows" gear-shaper system, for grinding the involute teeth of the cutters. The machine carries an emery wheel bevelled on each side to the shape of a rack-tooth with sides inclined at an angle of 29 degs. This wheel revolves at about 2,000 revs. per min. At the same time it moves bodily up and down through the space of tooth whilst the blank rolls under the restraint of two steel tapes, as in the "Bilgram" bevel gear planer. A few thousandths of an inch are left on the teeth for grinding, and the teeth are generated to the true involute form. One tooth is finished at a time and then the blank automatically moves forward to the next space. The amount of wear on the emery wheel is said to be small, and the wheel can be trued up in its place. Gears ground by these machines show a great improvement over those which have not been ground. Nevertheless, owing to the gradual wear of the emery wheel there is a difference between the first and last tooth finished in this way.

The author has devised a machine for grinding the involute teeth of gear wheels, which works on the principle of the hobbing machine. The teeth are generated simultaneously so that distortion due to the heating of the blank is eliminated, and, as the downward feed of the abrasive wheels is very rapid, the wear is practically negligible. The author has ground up several cast-iron wheels of 7 pitch on the experimental machine. The wheels are first hobbed, but the hob is not put into the full depth, so that a few thousandths of an inch are left on the sides of the teeth for grinding off. Before the wheels are ground the bottoms of the teeth are cut to the full depth with a specially formed cutter. It would, of course, be far better to hob the teeth in one operation with a hob having teeth that are slightly too thin. The wheel is then put on the work mandrel and the corundum worm moved down by hand until its centre is level with the top of the wheel to be ground. The corundum worm is then adjusted endwise by means of a screw turned by a worm and worm wheel by which a very fine cut can be put on, so that one side of the thread touches one side of the teeth in the wheel. Owing to the thread on the corundum worm being thin, the other side of the thread is not in contact with the teeth. The corundum worm is then allowed to feed down automatically, grinding up one side of all the teeth and generating them truly. The machine is then stopped, the corundum worm raised by hand, and a finishing cut taken. The other sides of the teeth are ground and finished in the same way. A stream of lubricant consisting of water, soda and oil is kept running on the wheel to prevent glazing. In the best results obtained so far a cast-iron wheel of 70 teeth 7 pitch and 1¼ in. face was completely ground in eight minutes.

The author's idea is that not case-hardened

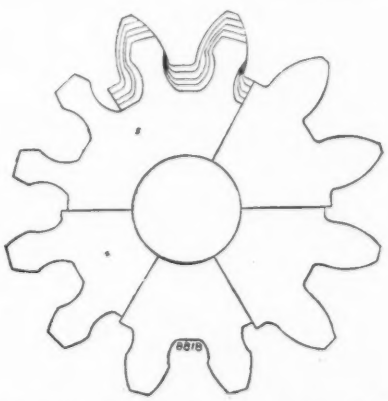


FIG. 15.—PORTIONS OF FIVE 12-TOOTH PINIONS CUT ON BLANKS SIZED FOR 11 TEETH UP TO 13 TEETH.

wheels only should be ground on this machine, but every kind of metal should be ground in the soft state, no matter for what purpose the wheels are required. The wheels would be roughed out rapidly in the gear hobbing machine with no attempts at finish, and then sent to the grinding machine to be finished, just as all lathe work that is required to be both accurate and cheaply produced is first roughed out in the lathe and then finished on the universal grinder.

From a paper read by Thomas Humpage M.I.Mech.E. at the Bristol meeting of the Institution of Mechanical Engineers.

Twelve-Wheeled Mallet Compound Locomotive for North China.

The engine forming the subject of the accompanying illustration is one of three Mallet articulated compound locomotives, recently constructed by the North British Locomotive Co., Ltd., Glasgow, to the order of Messrs. J. Whittall & Co., Ltd., London, for the Imperial Peking-Kalgan Railway of North China. The engine has been designed to haul heavy loads round curves of 500 ft. radius and up gradients of 1 in 30 of considerable length, the axle load being about 16 tons, and the total weight for adhesion 96 tons.

The prominent features of the Mallet type of locomotive are well known, the chief one being the flexible wheel-base construction, there being two distinct groups of driving-wheels, each group operated independently by its respective cylinders. The wheels of the rear or main-carrying frames are driven by two high-pressure cylinders, and the wheels of the front or motor-truck frames are driven by two low-pressure cylinders. The boiler is rigidly attached to the rear frames at the high-pressure cylinders, thus obviating the necessity for any flexible high-pressure pipe joints, and is further supported at the front end by a prolongation of the rear frame, which, in transferring part of the weight to the front truck, thereby relieves the boiler from all stress. The weight at this point is carried on a sliding bolster fitted with vertical buffer springs. Suitable provision is also made at front and back ends for the support and free expansion of the boiler. The front truck is connected to the main frame through a hinged joint formed by the cast-steel frame cross stays.

To accommodate the movements of the front truck relative to the rear frame the receiver pipe between the high and low-pressure cylinders is provided with a ball and socket joint at the hinged end, and a telescopic joint at the front end. There are also ball and socket and telescopic connections provided between the low-pressure cylinders and the blast-pipe. The lateral movements of the front frame are controlled by a horizontal side-check spring arrangement attached to the underside of the smokebox, and so arranged that it also forms an emergency bolster for meeting any abnormal stresses due to unevenness of the track or in case of derailment.

The two high-pressure cylinders fixed outside the hind frames are 18 in. diameter by 28 in. stroke fitted with Richardson balanced slide valves and anti-vacuum valves.

The two low-pressure cylinders fixed outside the front frames are 28¾ in. diameter by 28 in. stroke also fitted with Richardson balanced slide valves, anti-vacuum

valves, and water relief valves on each end at the bottom. Both high and low-pressure cylinders are provided with steam-actuated draining valves.

There are no intercepting or change valves used for starting purposes, the Mallet method being adopted, viz., a small auxiliary steam valve placed in the cab and operated by the driver is connected by a pipe to the receiver.

The valve-motion for both high and low-pressure cylinders is of the Walschaert type, the details being interchangeable throughout. Suitable adjustments are provided on the high-pressure reversing shaft lever for varying the relative cut-off periods in the high and low-pressure cylinders.

Reversing is effected by a steam gear controlled by a valve in the cab. One handle only is required to distribute the steam in the reversing cylinder and to lock or unlock the cataract valve on the water cylinder.

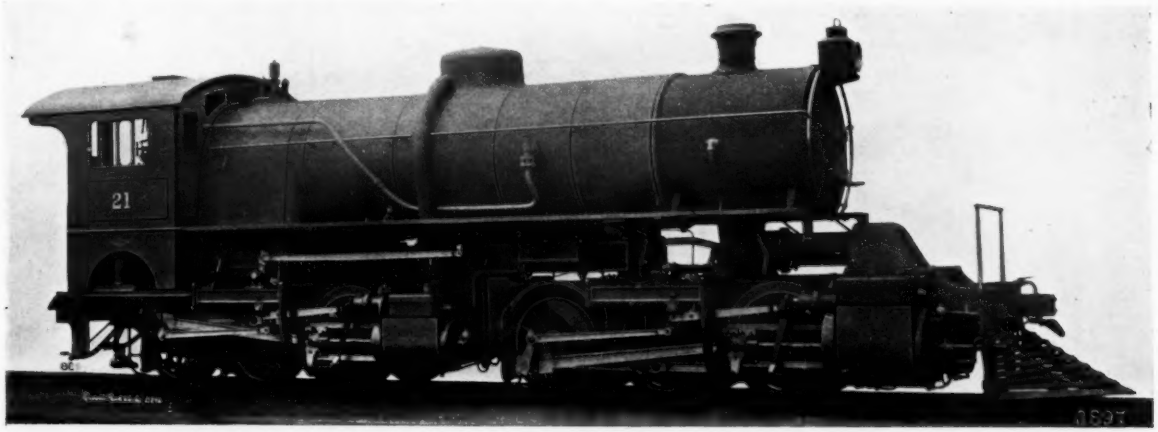
The engine is fitted with the Westinghouse automatic and also with the Westinghouse non-automatic or "straight" air brakes.

Air pressure is used to operate the sanding devices, the use of compressed air for this purpose obviating all trouble from condensed steam in the sand ejectors and traps.

The total wheel-base of the engine is 29 ft. 4 in., but only 9 ft. 8 in. is fixed wheel-base. The centre of the boiler above the rails is no less than 10 ft.

The cylinder lubrication is provided for by oil pumps and Furness-lubricators, and the boiler feed by two injectors. The grate is of the finger-bar type, and is operated by steam-gear. The safety-valves are of the Pop type.

It will be noticed from the illustration that the running boards provided are of the American type. This is in accordance with the North British Locomotive Company's practice for the standard engines of the North-China Railways. All the materials used in construction are the best of their respective kinds.



12-WHEELED MALLET COMPOUND LOCOMOTIVE FOR NORTH CHINA.

Vol. 19—No. 110.

The tenders for these engines are being built at the railway workshops in China.

We append a table giving the leading dimensions and particulars of the engine.

Gauge	4 ft. 8½ in.
Diameter of high-pressure cylinders	18 in.
„ low-pressure „	28½ in.
Stroke of pistons	28 in.
Diameter of coupled wheels	4 ft. 3 in.
Rigid wheel-base	9 ft. 8 in.
Total „	29 ft. 4 in.
Height of boiler centre	10 ft.
Heating surface, total	2,591 sq. ft.
Grate area	45·1 sq. ft.
Working pressure	200 lbs. per sq. in.
Weight in working order	96 tons.

Forced Lubrication for Axle-Boxes.

At the recent Bristol meeting of the Institution of Mechanical Engineers, Messrs. T. Hurry Richards and Bertie Reynolds described a system of forced lubrication as arranged for the driving axle-boxes of some of the steam cars of the Taff Vale Railway Company. Before entering into a detailed description of the system used, the author gave a few of the more necessary particulars concerning these cars.

The engine is carried on a four-wheeled truck of 9 ft. 6 in. wheel base and 2 ft. 10 in. diameter wheels, the boiler (of double-ended locomotive type, lying transversely across the frame) being placed immediately over the centre of the leading or driving-axle. The front end of the coach is supported by means of a bogie centre, carried between the frames at a distance of 4 ft. from the trailing-axle, or 5 ft. 6 in. from the leading-axle. When the car is loaded with its full complement of passengers, the weight on the driving-axle is 15 tons 13 cwts., the weight at the rail being 17 tons 6 cwts. The journals are 6 in. diameter by 9½ in. length; therefore, the pressure, taking two-thirds of the projected area of the brass as bearing area, is 466 lbs. per sq. in., the number of the revolutions of the journal, at a speed of 30 miles per hour, being practically 300. With this pressure and high rubbing velocity an undue amount of oil was being used with the ordinary method of lubrication, while cases of the bearings running hot were not infrequent, therefore the following arrangement for lubricating the journals under pressure was adopted.

To a cross-stay in front of the driving-axle, Fig. 1, a small gunmetal tank of rectangular section, Fig. 2, is fixed. On the side of this tank, nearer the driving-axle and in connection with the tank, two small rotary pumps—right- and left-handed—are fitted, the one for forward running and the other for backward running. These pumps are driven directly from the driving-axle by means of a belt passing over a flanged pulley carried midway between the pumps, the pulley containing on each side of it a roller-

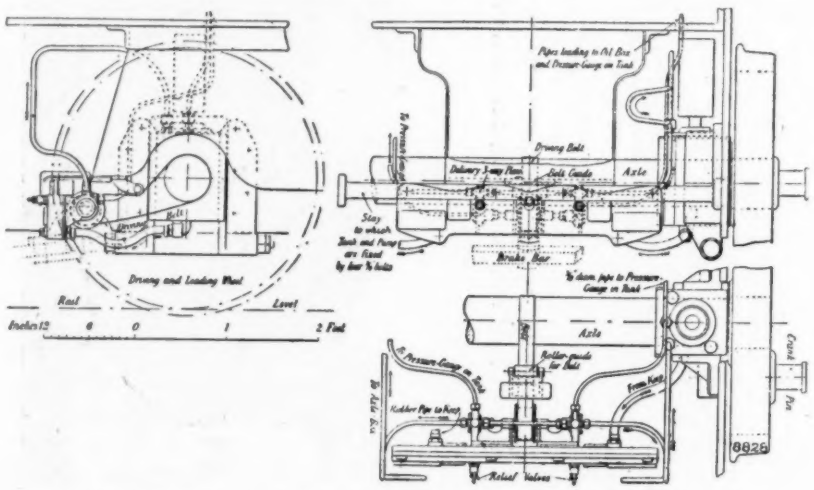


FIG. 1.—FORCED LUBRICATION APPLIED TO DRIVING AXLE-BOX ON TAFF VALE RAILWAY.

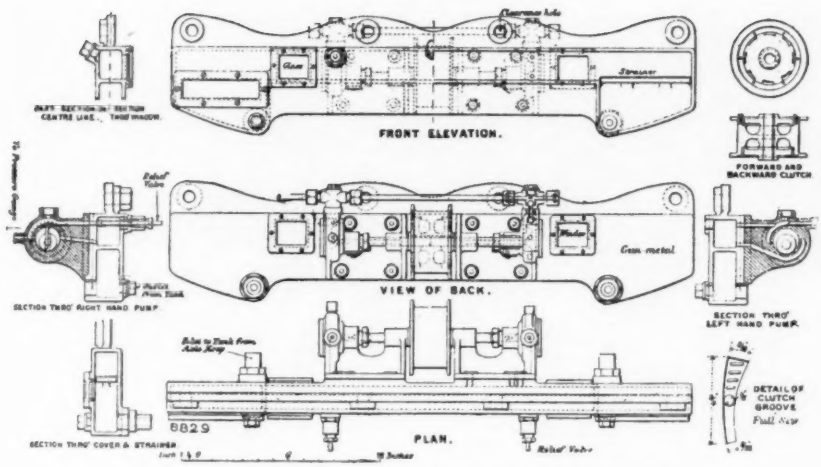


FIG. 2.—OIL TANK AND PUMP FOR STEAM CAR ON THE TAFF VALE RAILWAY.

clutch, somewhat similar to a free-wheel arrangement, fixed to the driving-spindle of the pumps. By these means, the one belt drives either pump forward or backward, the other pump being free.

Following the process through, for the lubrication of one of the journals, when the car is in motion, oil is pumped from the tank and forced through a coiled copper pipe to the top of the axle-box, Fig. 3. An oil channel, $8\frac{1}{4}$ in. long, $\frac{9}{16}$ in. deep, is cut in the crown of the box, leaving a margin of metal at each side of the channel of $\frac{3}{4}$ in. flat, which is found, when the box is properly bedded to the journal, to be quite sufficient to ensure that it shall be perfectly oil-tight at the pressures attained.

After passing round the journal, the return oil is collected in the axle-box keep, and from there is brought back to the tank by means of a flexible pipe which allows for the rise and fall of the axle-box, care being taken that the reservoir into which the oil is returned is sufficiently below the keep to drain it. At each side of the axle-box keep a half-ring is fitted with bearing area about $\frac{3}{4}$ in. wide. These half-rings are bedded well to the axles, and are supported upon a couple of small coil springs which hold the rings up to the journal with a fair pressure.

Many points arise, however, in regard to the working of the arrangement which it will be well to explain. In the first place, the pumps when running fast (at a speed of 30 miles per hour the revolutions of the pump are 440 per min.) deal with a greater quantity of oil than can be accommodated in the circuit at a pressure of, say, 20 lbs. per sq. in., above which, in practice, it has not been found advisable to work. A relief valve is therefore fitted to each pump with an adjustable spring which enables the pressure at which each pump shall work to be regulated. The excess oil, when pumping, simply passes back into the tank again, through the relief valve against the pressure of the spring. A small pressure-gauge connected to each pump, and fixed in the driver's cab, shows the pressure of the oil pumped on both forward and backward running, whilst also acting as an indicator should failure of either pump occur at any time. Should this happen from any cause, the ordinary system of lubrication, by means of a lubricating-box in the cab, is at hand. This lubricating-box is also necessary, to enable oil to be put into the axle-boxes after the car has been standing for a day or two, and so avoid starting away with dry axle-boxes.

To prevent the oil from the running pump flowing into the other pump and causing it to run backwards, a small ball-valve is placed in the three-way piece leading from each pump to the circuit. The movement of the axle-boxes relatively to the tank and pumps was met in the first instance by trying different sorts of flexible piping, but finally, ordinary coiled copper piping was adopted, both on account of its comparative durability and of its accessibility at any time.

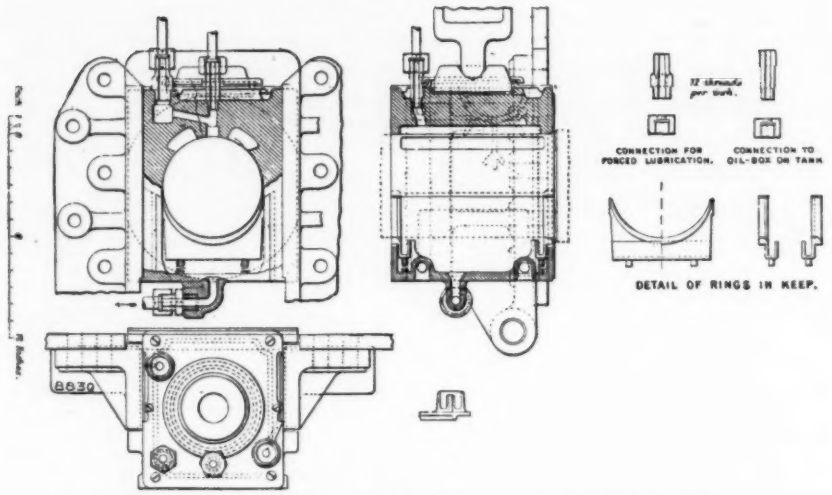


FIG. 3.—DRIVING AXLE-BOX AND KEEPS FOR STEAM CAR ON THE TAFF VALE RAILWAY.

The belt drive for the pumps at once gives a simple method of driving and one which allows for a small relative motion of the axle and pulley. It is apt, however, to soon become saturated with oil and then slipping occurs. An occasional application of one of the various belting mixtures, however, greatly reduces this slipping. When equal relief-valve springs were put in, it was noticed that the pressure indicated for forward and backward running varied considerably, probably due to the difference in the slip of the belt in each case. The filters in the tank are removable, and are taken out and cleaned at the end of each day's work, the oil being first drawn off through the stop-plug, the thicker part of the oil, after straining, being then replaced by a small supply of fresh oil.

The foregoing description shows one method of dealing with an everyday problem in connection with the running of railway motor-cars, or any rolling stock in which the pressure on the bearings, combined with the rubbing velocity, is excessive. The matter is one of importance to all concerned in the design and care of such stock.

First Class Dining Car, Lancashire & Yorkshire Railway.

The first-class dining car that has recently been constructed at the carriage and wagon department of the Lancashire & Yorkshire Railway, Newton Heath, to the designs of Mr. Geo. Hughes, chief mechanical engineer, forms another improvement in the Belfast boat train between Fleetwood and Leeds, and in the express service between Liverpool, Manchester and Leeds.

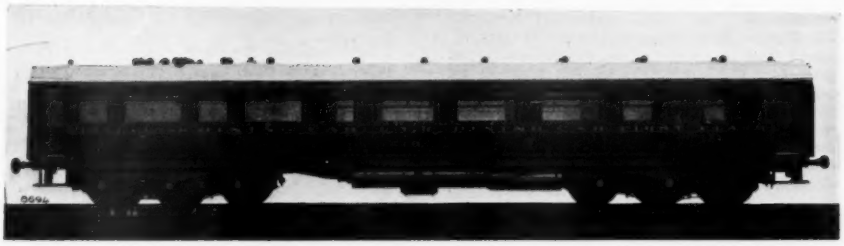
Several new points of interest have been introduced into the design, the chief of which are the elliptical roof, the width of the body, viz. 9 ft.—the limit of the company's load gauge, increased accommodation, and an excellent interior finish obtained by the larger capacity afforded.

The interior is divided into two passenger compartments for "Smoking" or "Lunching or Dining," accommodating a total of 33 passengers, a kitchen and pantry, together with a lavatory being arranged at one end, and vestibules at either end of the car, through which entrance is effected.

The principal dimensions are:—

Length over vestibules	65 ft. 6 in.
" " buffers	69 ft. 1 in.
Width over body	8 ft. 10½ in.
" " " cornices	9 ft. 0 in.
Height, rail to foot	12 ft. 4½ in.
" " to top of roof lamps	12 ft. 11⅞ in.
Centres of bogies	42 ft.
Wheel base of bogies	11 ft. 6 in.
Diameter of wheels on tread	3 ft. 6 in.
Total weight unloaded	38 tons 17 cwt. 3 qr.

The interior finish of the passenger compartments is in Spanish mahogany, with "Patapsco" veneer panels, millboard roofs painted white, and brass polished metal



FIRST CLASS DINING CAR, LANCASHIRE & YORKSHIRE RAILWAY.

fittings, with the exception of the table, bottle racks and ash trays, which are in polished nickel.

Electric bell communication is also provided at each table, and parcel racks over the seats and on the sides of the car. The latter has large side lights between each pair of seats, and over these, small hinged lights, which afford, with the roof extractors, ample means of ventilation.

Suitable photographs of places of interest, and also mirrors are arranged on each cross partition.

The seats are upholstered in "Epingle," and the floor covered with velvet pile carpet.

The whole car is lighted by incandescent gas lighting, and steam heated.

The kitchen and pantry are arranged in a thoroughly up-to-date manner, with cooking stoves, hot plate, multitubular boiler, refrigerator, ice chest, and every convenience for the storage of silver, china, cutlery, &c., special attention being given to ensure thorough cleanliness in every part.

The underframe and six-wheeled bogies are constructed entirely of steel, and are of the standard type for this class of vehicle. Each bogie weighs 6½ tons.

British Locomotives in 1907.

DESIGN.

On all, or almost all, the British railways a stage has been reached when the locomotives are, as a rule, well adapted to the duty they have to perform, and consequently are so well able to fulfil requirements that until some fresh development shall accrue in respect of the service demanded, little need exists for any material change in the methods now in vogue.

In respect of such details as the steam dome, elongated piston stroke, outside cranks, &c., British locomotive practice has definitely settled down to something like uniformity. For some time past, where deliberate departures from the prevalent practice have taken place, the Great Western has almost invariably been the "departer." The able chief mechanical engineer of that line, Mr. G. J. Churchward, still maintains his attitude of readiness to embrace any novelty that shall clearly seem to be an improvement. He adheres to his domeless coned boiler, and also, when two outside cylinders are used, to his 30 in. piston stroke. He would adhere also to his outside cranks—which have given such excellent results in his Atbara and City classes,—and to the inside cylinders which go with them, were not both of these put out of court by his necessary adoption of outside cylinders owing to his employment of a 30 in. stroke. Further, Mr. Churchward continues to build engines not only with his domeless coned boilers—which appear to give excellent results—but also with the very high steam pressure of 225 lb. per sq. in., which also is found entirely satisfactory in working. Hitherto, however, neither the coned boiler nor the 225 lb. steam pressure has found adoption on other British lines any more than the 30 in. piston stroke, so that all these three factors are at present distinctive features of Great Western practice.

THE 4-CYLINDER PROBLEM.

But his most important departure from the normal has been his extension of the use of four cylinders in single-expansion engines. I mentioned last year his experimental employment in 1905 of four cylinders instead of two in his non-compound Atlantic "North Star." In 1907, however, he applied the same principle to ten new locomotives of his very successful 4-6-0 express type, all of which have been in regular service for some months, and which have given entirely satisfactory results in respect of the work actually performed, as I shall show later. The Great Western, however, does not stand alone in the use of four cylinders in single-expansion locomotives. Mr. D. Drummond also has employed them for some time on the London and South-Western in the case of five 4-4-0 express engines, and has now introduced them with his very large and heavy type of 4-6-0 locomotives.

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As in the case of so many other special features of locomotive designs, the question which has to be faced is not so much the efficiency and usefulness of the plan as its relations to economy of construction or work. In this instance the problem to be solved is—whether the advantages undoubtedly derivable from the employment of four cylinders instead of two are or are not purchased at a cost in excess of the value obtained. No one disputes, or can dispute, the fact that with four cylinders more even working, superior balance and equilibration, and enhanced steadiness of running, can be secured. It is equally indisputable that four cylinders, with all their gear and accessories, must needs cost much more than two, alike in construction and in repairs. The expectation—or at least the hope—of those who advocate the four-cylinder method is that through the improved equilibration and the smoother and easier running obtained, not merely will the wear and tear, and consequently the amount and expenses of repairs, be appreciably reduced, but also increased duty will be got out of the engine through large diminution of internal resistance. Theoretically this should be the case. Practically it will be found, I suspect, to depend a good deal upon the circumstances and conditions of working. Thus the one locomotive of this type designed and built for purposes of comparison by the late Mr. F. W. Webb, for the London and North-Western—viz., No. 1901, then named "Iron Duke"—was confessedly a failure, not, however, because of the principle, but merely owing to the utter inadequacy of the boiler power provided to fill with live steam four cylinders each 15 in. by 24 in. In that case, however, the boiler had been designed for a compound type which had only two instead of four 15 in. cylinders to be filled with live steam, and so its insufficiency when called upon to supply a double volume of cylinder cubical capacity was a foregone conclusion.

As regards the five earlier four-cylinder locomotives designed and built by Mr. D. Drummond for the London and South-Western, which are of the 4-4-0 order, they appear to have done very good work since a satisfactory co-relation was arrived at between the respective capacity of boiler and cylinders. To the newest London and South-Western engines of the four-cylinder type, which are of the 4-6-0 order — those of the 3 3 0-3 3 5 class — Mr. Drummond has given vast boilers which should be fully capable of meeting all cylinder demands, and so they should prove useful machines. They seem, however, to partake more of the express goods than of the passenger express type. The Great Western four-cylinder engines, on the other hand, have been specially designed and constructed by Mr. Churchward for the fastest as well as heaviest work on that line, which is famed for the speed and for the long non-stop runs of its best expresses. This work they assuredly perform to admiration. Alike in swiftness and in haulage power they have no superiors—if any equals—on the Great Western.

It is true that the pioneer of the four-cylinder type, "North Star," has not given unqualified satisfaction, but this has been merely because her adhesion weight, being on only four wheels, has occasionally proved insufficient to utilise the large steam power provided by her four cylinders with her steam pressure of 225 lb. per square inch, but the other ten now at work, Nos. 4001-4010, of the 4-6-0 class known as the "Dog Star" set, have given performances so fine in respect alike of speed, weight pulling, and gradient climbing, that they would seem to have reached a point beyond which progress is hardly feasible under existing conditions, if indeed any more be readily needed than these fine engines can supply. It is true that their designer is not satisfied that he has reached such a point, and considers that he has yet "fresh fields to conquer," so he has designed and built a still more potent machine, of the so-called Pacific or 4-6-2 order, which would certainly seem to represent the ultimatum of *ne plus ultra* of the single-expansion express locomotive under any condition not known to exist —in Britain, at any rate. Such forecasts, however, are seldom trustworthy, and locomotive engineering may have startling novelties in store for us yet.

Mr. Churchward's new colossus, No. 111, which inaugurates a fresh class of standard nomenclature, and is named "Great Bear," is by far the largest, heaviest, and most powerful locomotive ever yet seen in Great Britain. Measuring 71 ft. 2¾ in. in total length over buffers (including tender), and having a total weight in working order of 97 tons 5 cwt., exclusive of her eight-wheeled 45¾-ton tender, or just 143 tons including tender, while her boiler is no less than 23 ft. in length and 6 ft. diameter, with a total heating surface of 3,400 sq. ft., "Great Bear" represents an entirely new departure for these islands. Apart from her enlarged dimensions and her extra pair of carrying wheels in the rear, the engine is mainly a reproduction of the 4-6-0 "Dog Star" class already referred to. The same working steam pressure is carried—viz., 225 lb. per square inch,—and also the same piston stroke, 26 in., but the four cylinders are 15 in. diameter instead of 14½ in., as in the case of the "Stars." The valves are of the piston type, and the boiler, which is of the "extended wagon top" order, is fitted with a superheater of special design, as also is the Belpaire firebox. The grate area is no less than 41·79 sq. ft. The total weight of 97¾ tons is distributed as follows: On the leading bogie, 18 tons 12 cwt.; on each of the three pairs of 6 ft. 8 in. coupled wheels, 20 tons 9 cwt.; on the radial trailing wheels, 17 tons 5 cwt. The new engine only made her appearance at the extreme end of the year, and so no opportunity has yet offered of testing her capabilities, which, however, can hardly fail to prove greatly in excess of anything yet seen in the United Kingdom.

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The second main novelty of the year has been a gigantic tank engine, designed for the very heavy shunting duty of the Great Central Railway, at the Wath concentration yards, by Mr. J. G. Robinson, the able chief mechanical engineer of that line. These monster goods engines, curiously enough, weigh almost exactly the same as the Great Western Pacific engine, which is a passenger express—viz., a fraction over 97 tons. The Great Central locomotive is an eight-coupled trailing bogie tank, having three high-pressure cylinders, but is not compounded. Each cylinder is 18 in. by 26 in., and the cranks work at an angle of 120 deg. The eight-coupled wheels are 4 ft. 8 in. diameter, and their wheelbase is 17 ft. 1 in. The boiler and firebox are the same as those of the standard express engine of the Atlantic type described and illustrated by me three years ago. That is to say, the heating surface is 1,911 sq. ft. and grate area 26 sq. ft. The tank and bunker spaces are so large that no less than five tons of coal and 3,000 gals. of water can be carried—as much as many tender engines.

These are beyond question the most powerful goods engines of any class in the United Kingdom. They have been found to push seventy loaded coal wagons without difficulty or assistance up an incline of 1 in 100. Mr. Robinson contemplates another new departure in the three-cylinder direction by thus fitting one of his Atlantic class. Already, as I have previously mentioned, Mr. Robinson has given to some of this class a third cylinder, making it a three-cylinder compound. But under the new plan the locomotive will be of the single-expansion type. The third cylinder will be 15 in. or 16 in. diameter, and the cranks 120 deg. apart. It will be most interesting and instructive to see whether this novel method proves to be substantially and economically advantageous. My own opinion is distinctly favourable.

It may perhaps be permissible here to express in passing some surprise that, excepting in the case of these tank engines and Mr. J. Holden's experimental Great Eastern decapod, no adequate trial has been made of the plan of having three high-pressure cylinders, which would seem to give virtually almost all the advantages derivable from four cylinders, and at a materially diminished cost of construction, while the doubly-cranked driving axle would be replaced by a singly-cranked one—apparently an advantage. However, the method, though theoretically approved by some authorities, has not yet found practical favour on any other British lines.

COMPOUNDING.

Still more noteworthy is the fact that the strong disinclination on the part of British mechanical engineers to adopt the compound principle in locomotives seems to remain almost as indomitable as ever, notwithstanding the excellent results achieved under Mr. De Glehn's system on the Continent, and recently by the system of the late Mr. Walter Smith, as well as that claimed for the methods of Messrs. Mallet, Worsdell, von Borries, and Vauclain. The three express compounds imported from France for the Great Western Railway, all of the Atlantic or 4-4-0 class, and designed by Mr. Du Bousquet, chief mechanical engineer of the Chemin de Fer du Nord, on Mr. De Glehn's four-cylinder balanced compound system, continue to do regular work on the Great Western in competition with that line's British-built single expansion locomotives of approximately identical nominal power. In my article of last year I drew attention to a seeming discrepancy in the results reported by Inspector R. H. Smith. He has since, however, explained to me that the British-built Great Western engines which the Frenchmen beat were the four-coupled ones of the older Atbara and City classes, which had smaller boilers and only 195 lb. steam pressure, as against the French engines' 228 lb. But when tried on equal terms against the later Swindon-built engines of the 4-6-0 and 4-4-2 classes, which have far larger boilers and 225 lb. steam pressure, also a 30 in. piston stroke, he assures me that the British locomotives were able to pull 5 tons additional weight under identical conditions of speed, load and road. I give this information as received, merely venturing the remark that, as in the case of the De Glehn compounds, admittedly so much depends upon the way they are worked, that it is conceivable that the difference between Continental and British methods and fuel may account for the work done in this connection being apparently less satisfactory than that achieved abroad. In any case, however, the position is not that the compounds have done poor work—for it is freely conceded that their performances have been excellent—but it is maintained that the Great Western non-compounds have done still better.

Assuming that all the conditions of working were really equal, the reasonable inference would seem to be that to the extra-high pressure rather than to the system of compounding may have been partly due the remarkable superiority of work observed and recorded by men on the French railways. But sufficient information is not yet available to warrant a definite opinion being pronounced on this head. One of the Great Western French engines has already been reboilered, one of the line's standard boilers with ordinary smooth-bore tubes having been substituted for the original Servé-tubed boiler with which the engine left the Belfort shops. So far the Servé tubes, with their large diameter and internal ribbing, do not seem to have found favour in Britain. When Mr. S. W. Johnson built his first batch of three-cylinder compounds for the Midland line, he fitted some with Servé tubes, but these have since been removed and replaced by the ordinary smooth-bore type, trouble having been found in keeping the others "tight." These compounds, of which many have been constructed by Mr. Deeley, the present locomotive superintendent of the Midland Railway, with increased steam pressure

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220 lb. instead of 195 lb., appear to be giving full satisfaction. I have always found them to do capital work. Such has also been the case with the fine Atlantic engines compounded on a similar principle by Mr. J. G. Robinson, chief mechanical engineer of the Great Central Line, which I described two years ago, and about whose work I shall have something to say later.

I may note here that I am of course unable to give of my own knowledge the comparative results obtained, either in the case of the various compounds or of the four-cylinder and two-cylinder classes—as regards relative merit of work, cheapness of construction, or economy of maintenance. The figures under those heads belong to the more private and inner workings of a railway, and are rarely disclosed to outside engineers. My function is to record the actual work which I have personally observed and registered. This at least constitutes a fair and trustworthy standard of comparison in respect of duty done.

As regards the other British lines, I have but little to record of special interest. Summarising the facts, and taking the various railways in their usual order, I may say that for the London, Brighton and South Coast no fresh express locomotives have been built since Mr. D. Earle Marsh's Atlantics which I illustrated two years ago, but Mr. Marsh has designed and constructed an experimental tank engine for express service which promises to give excellent results. It is of the 4-4-2 type, and resembles in outside appearance the London and North-Western passenger tank which I illustrated last year, but has somewhat larger coupled wheels—6 ft. 9 in. instead of 6 ft. 3 in.—and smaller boiler——1,625 sq. ft. of heating surface. The cylinders, however, are identical, 19 by 26. Also Mr. Marsh has brought out a set of very fine new ten-wheeled tank engines, closely resembling the 4-4-2 tank class constructed for the Great Northern during his Doncaster management, also a useful class of six-coupled goods engines.

On the South-Eastern and Chatham Railway, Mr. H. S. Wainwright has continued to build the efficient 4-4-0 engines which he introduced on his accession to the locomotive control of the railway, the earlier ones having 6 ft. 8 in. coupled wheels and 19 in. cylinders, the later ones 6 ft. 6 in. coupled wheels and 19½ in. cylinders with Belpaire fireboxes. On the Great Eastern, the only new development is a personal one, consisting in the regretted retirement of Mr. J. Holden and the appropriate succession of his son, Mr. S. D. Holden, who has been specially trained under his able and eminent father. For the Great Northern, Mr. H. A. Ivatt has turned out more of his powerful Atlantics, and has added another four-cylinder compound of the same class and general dimensions as his earliest one, No. 292. He has also put on a new suburban tank type with six-coupled wheels and trailing radial-axle. Mr. G. Whale has built more of his remarkably effective so-called Precursor 4-4-0 and Experiment 4-6-0 class for the London and North-Western, and Mr. F. M. Deely has brought out a new single expansion 4-4-0 engine, No. 999, on the Midland, which has no exceptional characteristics. Its cylinders, placed inside the frames, are 19 by 26, and the four-coupled wheels 6 ft. 6 in. diameter. On the North-Eastern, Mr. Worsdell is multiplying his 2011 class, 4-4-0, with 6 ft. 10 in. coupled wheels and inside cylinders 19 by 26, which I described and illustrated in my notes for 1899. On the Great Central Mr. Robinson has built two more of his compound Atlantics.

WORK.

In reviewing the salient features of the year's work as it came under my observation, I shall take it, as usual, purely in the order of succession in which the British railways are given in Bradshaw, without any necessary relation to the order of merit.

As it happens, however, the two orders coincide in the case of the Great Western Railway. The non-stop runs by that line between London and Exeter, 173¾ miles, in the even three hours, averaging 57·9 miles an hour; between London and Bristol, 118½ miles, in the even two hours, averaging 59·2 miles an hour, surpass anything in the rest of the world in respect of combined speed and length; while the non-stop run between London and Plymouth, 225¾ miles, in 4 hrs. 7 min., including several gradients of excessive steepness —*e.g.*, 2¼ miles on end at 1 in 42, and a separate short length at even 1 in 40,—has in its way no equal in the whole world. The loads, too, of the best trains, originally strictly "limited," and still professedly so, have steadily grown until, during the summer of 1907, these erroneously styled "limited" expresses often reached and exceeded 350 tons behind the tender, sometimes approximating 400 tons.

To grapple with such loads and gradients and booked speeds as these, Mr. Churchward designed and built his 4-6-0 engines of first the two-cylinder and then the four-cylinder types—viz., the 2901 and 4001 classes respectively,—and these have proved fully equal to the severe duty imposed upon them. So have the Atlantic or 4-4-2 type when slipping could be avoided, which, owing to the insufficient adhesion weight given by four-coupled wheels with such large steam power, was not always possible. No. 40, "North Star," the only four-cylindered Atlantic, hauling 290 tons behind the tender, covered the 225¾ miles from London to Plymouth in 4 hrs. 1 min. 18 sec. inclusive; 3 hrs. 52 min. net, allowing for signal and permanent-way delays. Descending the Bruton bank maximum rates of 81·8, 83·7, 85·7, 88·2 and 91·8 miles an hour were attained, the running at the time being absolutely smooth and free from oscillation. The minima up the Dainton and Rattery banks—1 in 43 and 1 in 48—were 23·7 and 25 miles an hour respectively.

In the opposite direction, No. 2908, "Lady of Quality," two-cylindered 4-6-0 class and 200 tons, made the exceptionally hard run from Plymouth to Exeter, start to stop, in 62¼ min. for the

52 miles, sustaining a steady rate of 23·7 miles an hour up the Hemerdon bank—2¼ miles at 1 in 42—and "rushing" the steeper though shorter Rattery incline of 1 in 40 at a minimum of 33 miles an hour. A new two-cylindered four-coupled engine, No. 3820, "County of Worcester," continued the same journey from Exeter to London, with the same load, making the run of 173¾ miles without stop in 2 hrs. 57 min. 20 sec., and covering the final 142 miles from Taunton (pass) to London in 143 min. 54 sec.

The four-cylindered six-coupled bogies gave me several good runs. No. 4001, "Dog Star," the pioneer of the type, with nearly 300 tons behind the tender, ran from London to a stop at Exeter in 2 hrs. 56 min. net, in spite of a very severe side gale. The lowest speed up the Wellington bank, 1 in 80, was 41·6 miles an hour, in spite of the retarding effect of the side gale. On more favourable lengths of the road rates of 80·3 miles an hour and 83·7 were attained. In the opposite direction No. 4002, "Evening Star," of the same class, with 220 tons, ran from Exeter to London, 173¾ miles, in 2 hrs. 56 min. 47 sec. inclusive, from start to stop, notwithstanding the continuance of a heavy side gale throughout the entire journey. The minimum up the Bruton bank, 1 in 80, was 42·9 miles an hour, the maximum on a falling gradient 79·1. Thus the swiftness of the six-coupled type is abundantly established. A third performance by this type was also remarkable. The engine was No. 4006, "Red Star," and the load approximately 300 tons behind the tender. Once more a hard side gale impeded us greatly. Nevertheless the run of 118½ miles from London to Bristol was accomplished in 115¼ min. net, and coaches were slipped at Bath, 107 miles, in 103¾ min.

A fourth run is worth noting. The engine was again No. 4001, "Dog Star," but the load in this case was no less than 340 tons; a furious cross wind was again blowing, and no fewer than five bad signal checks delayed us. Yet we ran from Bath to London in 102½ min. net. An engine of the older Atbara 4-4-0 type, No. 3406, "Ophir," with 190 tons, made several times the extraordinary long non-stop run of 262½ miles between London and the Irish-service port, Fishguard, in 4 hrs. 50 min. to 4 hrs. 58 min., travelling most of the distance under relatively easy steam. On the first occasion Swindon, 77¼ miles, was passed in 76 min. 16 sec.; Badminton, 100 miles, in 99 min. 58 sec.; Newport, 133½ miles, in 138 min. 42 sec.; and Cardiff, 145¼ miles, in 153 min. 14 sec., these last two times being the quickest ever made to those stations, which, moreover, had never before been passed without stopping. The length of run without stop has only been exceeded in Britain by those of the London and North-Western from London to Carlisle, 299 miles, and to Holyhead, 264 miles, but in each of these cases the speed was lower.

My most noteworthy experience on the London, Brighton and South Coast was a run with the Sunday Pullman-car train from Brighton to London (Victoria) with one of Mr. D. Earl Marsh's new express engines of the 4-4-2 or Atlantic type, illustrated by me two years ago. This particular engine was No. 40, and the load, including passengers, luggage, &c., was approximately 250 tons behind the tender. The run of 51 miles *viâ* the deviation line, which is somewhat longer than the older route, was performed with ease in 54 min. 25 sec. from start to stop. This was, of course, beaten five years ago in point of time, but with a load of 50 per cent. lighter, and by running at far higher speeds on falling grades. One special feature of the present performance was that so skilfully did the driver manage the engine that almost exactly identical speeds were maintained uphill and downhill alike. The ruling grade is 1 in 264, and each way the speed was kept steadily at 60 to 65 miles an hour, whether ascending or descending. This was very creditable to Mr. Marsh's fine engine.

On the South-Eastern and Chatham Railway I had an excellent run from Folkestone to London with one of the latest 4-4-0 engines, designed and built by Mr. H. S. Wainwright, those already mentioned as having 6 ft. 6 in. coupled wheels and 19½ in. cylinders. These engines may seem relatively small as compared with the huge machines in use on the Great Western and other lines, but their merit consists in their being exactly proportioned to the work which they have to do, and for which they were specially designed. Thus, in this instance the train was the standard boat express, crowded from end to end with passengers and luggage, and weighing in all over 300 tons behind the tender. The engine was No. 273. The time allowed for the 70 miles is 94 min., but the grades are very heavy, including a long stretch at 1 in 120 approaching Sevenoaks tunnel. The engine, however, after once attaining speed, kept a persistent 60 to 65 miles an hour uphill and down, excepting on the severe bank just mentioned, and here speed never fell below 30 miles an hour. The full time from Folkestone to Charing Cross was 87¾ min. net, and the travelling all that could be desired in respect of smoothness.

Turning now to the more Northern lines, I may mention a performance by one of Mr. H. A. Ivatt's latest Great Northern Atlantics, No. 1414, which took a Scotch express of 400 tons weight behind the tender from London to Grantham, 105½ miles, in 2 hrs. 4 min. 58 secs. Up the long bank at 1 in 200 continuously for 8½ miles the lowest speed was 36 miles an hour, with that enormous load, and the same minimum rate was sustained up the somewhat steeper Stoke bank of 1 in 178, while a maximum downhill speed of 80·3 miles an hour was more than once attained. The times from King's Cross to the various points were:—Potter's Bar summit (12¾ miles), 22 min. 44 sec.; Hitchin (32 miles), 43 min. 5 sec.; Peterborough (76¾ miles), 87 min. 2 sec.; Stoke summit (100 miles), 119 min. 29 sec. With the corresponding train in the opposite direction, No. 1427, of the same class, hauling 250 tons, ran from Doncaster to London, 146 miles, without stop, in 2 hrs. 58 min. 40 sec., necessarily easing down toward the end to avoid unduly early arrival.

Several runs on the London and North-Western with Mr. G. Whale's engines of the Experiment

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(4-6-0) and Precursor (4-4-0) types respectively were of interest. No. 66, "Experiment," the pioneer of the class, took a gigantic train of 402 tons behind her tender from Euston to Crewe, 158 miles, without stop, in 2 hrs. 59 min. 23 sec., averaging 52·7 miles an hour with that huge load on a road by no means easy. The lowest speed up the long bank at 1 in 330 to Tring was 50 miles an hour, the general rate up that rise being 52·2. A like rate was maintained up the later ascents to Roade and to Kilsby Tunnel, and a maximum of 70 to 72·6 miles an hour was reached down falling grades. But on the level and on the easier grades the work was less satisfactory, the pace often failing to exceed 50 on the level and dropping to 45 on the easy up grade of 1 in 660.

It has been suggested in explanation that the six-coupled wheels may be too small, 6 ft. 3 in. for the size of the boiler, thus requiring the cylinders to be filled too frequently at high speeds when unaided by gravitation; but I am not entirely satisfied by this theory. In another case, a sister-engine, No. 1956, "Clanricarde," performed admirably in all respects with 380 tons behind her tender, sustaining an uphill minimum of 50 miles an hour at Tring, 53 to Roade, 52·8 to Kilsby Tunnel, and reaching Rugby, 82½ miles, in 90 min. 32 sec. from the Euston platform. Making a fresh start, the next stage of 75½ miles to Crewe was run in 82 min. 39 sec. from platform to platform. In each case a maximum of 72·6 miles an hour was attained downhill.

Another locomotive of the same type, No. 2052, "Stephenson," took me from Crewe to Carlisle, 141 miles, in 2 hrs. 38 min. 52 sec. actual travelling time, or 2 hrs. 36 min. net, passing Warrington (24½ miles) in 24 min. 53 sec. from the Crewe start; Preston (51 miles) in 54 min. 34 sec., and never falling to 40 miles an hour up 1 in 110 on the Grayrigg bank, also attaining 80 miles an hour downhill. The load, however, was relatively light, barely 200 tons, and we had a bank engine up Shap incline. Still the work was distinctly good. In the opposite direction, another of the class, No. 1991, "Palmerston," with 350 tons, ran from Carlisle to Crewe without stop in 2 hrs. 50 min. 39 sec. for the 141 miles, but was hampered by having to ease down, being much before time.

The Precursors, or 4-4-0 type, continued to do well. No. 2012, "Penguin," took me from Crewe to Rugby, 75½ miles, in 80 min. 28 sec., with 350 tons behind her tender, and No. 635, "Huskisson," went on with the same load to Euston in 88 min. 54 sec. for the 82½ miles. Finally, No. 2064, "Jason," with 320 tons, did the run of 128 miles from Stafford to Willesden Junction in 134 min. 19 sec. from start to stop, the time for the 77 miles from Rugby to the stop being 79½ min.

My experiences on the North-Eastern were virtually confined to some runs with Mr. W. Worsdell's four-cylinder Smith compound Atlantics. No. 730, hauling 300 tons, took the day Scotch express from York to Newcastle, 80½ miles, in 87 min. 49 sec., thus gaining 10 min. 11 sec. on booked time, and arriving 8 min. early, in spite of two bad checks for signals and relaying, which cost us over 3 min. delay. Darlington, 44½ miles, was passed in exactly that number of minutes. Up 1 in 120 the speed never fell below 53 miles an hour. The downhill maximum was 75, but we were running under easy steam, being so much before time. With the first two Great Central compounds, Nos. 258 and 259, I recorded some excellent work. The former ran from London (Marylebone) to Leicester, 103 miles, in 108¾ min., covering the 65 miles from the Aylesbury slack in 63 min. 33 sec. In the opposite direction, No. 259 ran from the Leicester start to a signal stop, 57 miles, in 52 min. 53 sec., and reached High Wycombe, 79½ miles, in 76 min. 24 sec. actual travelling time, or 74 minutes net. This was very smart work, but it must be confessed that the loads were light, barely 120 tons behind the tender in each case.

Crossing the border into Scotland, I have to note one excellent piece of work on the part of the Caledonian Railway. No. 907, one of Mr. J. F. McIntosh's 4-6-0 type, with inside cylinders 20 by 26, 6 ft. 6 in. coupled wheels, and 2,400 sq. ft. of heating surface, took me from Glasgow to Carlisle, 102 miles, in 2 hrs. 2 min. net travelling time, the load being 350 tons behind the tender. The lowest speed up the 1 in 100 approaching Beattock Summit from the north was 34·6 miles an hour, and the pace was carefully eased during the latter part, so as not to reach Carlisle too early. Thus we took 50 min. 55 sec. to make the descent of 49¾ miles from Beattock Summit to Carlisle, which I have often done in 5 or 6 minutes less time. It was in the gradient-climbing that Mr. McIntosh's engine showed to chief advantage, a very important matter in the case of a line so severely graded as the Caledonian. Another of Mr. McIntosh's newest engines of his special 4-6-0 type—all of which have inside cylinders.—No. 908, illustrated by me last year, which has 5 ft. 9 in. coupled wheels, instead of 6 ft. 6 in. like the 49 class, or 5 ft. like the "Obans," sustained a rate of 31 miles an hour up the Dunblane bank (1 in 73), hauling 250 tons.

No other experiences of mine on the British railways during the past year demand special notice. I may add that all the observations given were, as usual, made by myself personally, and that all the train-weights are exclusive of engine and tender, also in accordance with the rule I have invariably adopted.

C. Rous Marten. Bulletin of the International Railway Congress, 1908.

By ANDREW STEWART, A.M.I.E.E.

Turbo-Electric Marine Propulsion.

Among the papers read to the Institute of Marine Engineers, at their summer meeting, that by Mr. W. P. Durtnall* on the above subject supplied much food for reflection. Briefly put, Mr. Durtnall's scheme is to improve the recognised (?) inefficiency of the steam turbine propelled vessel, by providing it with electric generators and slow speed polyphase induction motors, the latter driving the propellers, which, at slow speeds, are alleged to be more efficient than at the higher speeds, which, however, are essential if the turbine itself is to be efficient.

While it is admitted that the screw propeller at high speeds introduces phenomena which is non-existent or negligible at the more moderate speeds hitherto usual in marine propulsion, it is much to be doubted if the conversion of mechanical into electrical, and back into mechanical energy, is likely to add to the sum total of the efficiency.

By some obscure mathematical, or perhaps mental process, the author arrives at the conclusion that a saving of from 20 to 25 per cent. can be effected in the steam used by marine turbines if the speed is raised to the extent permissible with high speed turbo-electric generators, and then proceeds to state that, generally speaking, a saving of 30 to 40 per cent. is possible. If he succeeded in convincing his audience that, after the double conversion of energy, with its attendant losses, such economies were possible, he possesses a persuasive eloquence which is wasted in the engineering profession, but which would reap a bountiful harvest in the political world.

The figures do not support such claims to economy, though we suspect the author was nearly giving his case away when he said that the generators such as he proposed only required about 2 per cent. of the total output for excitation, and then put the upper limit of efficiency at 98 per cent. Some designers are looking for alternators which have no iron, copper, bearing friction, and windage losses; they are not, however, unduly optimistic as to the result, but the author's enthusiasm seems equal to anything.

Mr. Durtnall appears to have entirely ignored the fact that even the turbine steamer *King Edward*, one of the earliest of the type, built at a time when we knew a little less about high speed propellers than we now do, gave results as to steam consumption which were in no way inferior to ships engined with slow speed engines. Still later, the Midland Railway Company made exhaustive trials of identical steamers engined with reciprocating engines, and with steam turbines, which demonstrated that despite cavitation and similar phenomena associated with high speed propellers, the turbine-propelled ship was no less efficient.

Some two years ago we described in this column a marine installation where an oil engine and generator supplied power to drive the electric motors on the propeller shaft. The object in that case was quite definite and readily understood, viz., to secure the economy of the Diesel engine, and also the flexibility of the electric motor for propulsion in a district where coal was expensive and oil comparatively cheap. Even in that case, however, where the circumstances were far more favourable than ever they are likely to be in marine work round our shores, the arrangement was subsequently modified so that the oil engines were coupled direct to the propellers,

* See p. 180.

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and the electrical plant only used when manœuvring into, or out of, a harbour. The chief reason for the change was that the double conversion of energy wasted all that was gained by the more economical engine. This double conversion of energy, even if the electrical plant can be had for nothing, is sure to kill any scheme of the kind, and naval architects and marine engineers will prefer to spend their time investigating the performance of the screw propeller at high speeds, to wasting their efforts designing ships filled with machinery to waste energy. Moreover, we doubt if the paper itself, filled as it was with self-contradictory figures, reinforced by arguments that any associate of the institution would have no difficulty in refuting, impressed the meeting as more than a waste of energy; British naval architects are too practical to adopt such a long way round a problem that is merely incidental to the steam turbine.

Electric Traction on the Midland Railway.

Nothing so forcibly illustrates the aloofness which the various railway companies in this country display towards each other, than the isolated experiments that are being made in electric traction. In no case do these experiments do more than demonstrate the success or failure of electricity under a given set of conditions, for so far, no experimental line has dealt with the general traffic which the company as a whole has to handle. The North-Eastern and the Lancashire and Yorkshire electrified lines are essentially busy suburban lines, the traffic on which bears no resemblance to the general traffic of the system, and can therefore convey no useful lessons as to the latter.

Such experimental work is no doubt partly the result of expediency, and partly timidity, for there is naturally a disinclination to undertake work which involves more than a small step in advance. Progress under such circumstances must be slow, for the problem of railway electrification is essentially a general one; indeed, the handling of the vast merchandise traffic of our railways is of such importance that no system, no matter how satisfactory on the isolated scraps of line which are now being operated electrically, can be considered of any practical value if it does not lend itself to the efficient and economical handling of goods and mineral traffic, yet this is just the side of the problem that is being ignored.

Perhaps, in view of the development of more cordial relations between the various railway companies, a joint board, or other experimental authority, may be constituted, which will attack the problem vigorously, by electrifying a sufficiently large stretch of line handling mixed traffic, to determine the general suitability of direct or alternating current for general railway purposes. Such work would be conclusive, or if not, would at least clear up many obscure points, while existing experiments are only confirmatory of previous experiments of a similar nature.

No one, for instance, doubts that a single phase motor will rapidly and economically handle the passenger traffic between Morecambe and Heysham, a direct current system would no doubt be equally satisfactory. The capital cost can be calculated with considerable accuracy, while the equipment can be obtained from several firms who have done such work elsewhere. That is about all that can be said for it, as it cannot be pretended that it solves a single important problem dealing with the question of general railway electrification.

Electric Power at Cargo Fleet Iron Works.

Until 1905 this firm produced pig iron only, but it was then decided that the production of structural steel would be advantageous, and the plant was remodelled accordingly. It is the first in Great Britain to combine a blast furnace plant and steel works. Originally there were five blast furnaces 75 ft. high with a 24 ft. bosh; the new furnaces, of which there are only two, are 90 ft. high, with a 21 ft. bosh, and produce 1,400 tons of pig iron per week.

The blowing engines are Cockerill gas engines by Richardsons, Westgarth & Co.

There are no men employed at the top of the furnaces, the charge of calcined ore, limestone, and coke being shot from large storage bins into the skip of a Brown hoist charging equipment. The ingredients already referred to being automatically weighed during their passage to the charging gear.

The generating station, which aggregates 3,300 kw., consists of a variety of prime movers, due, of course, to the different sources of power available. There is a vertical compound steam engine, two steam turbines, two Premier gas engines operating on coke oven gas and two more on blast furnace gas. The blast furnace gas is

thoroughly cleaned before being used ; this cleaning applies not only to the gas used in the engines but in the furnaces also ; three Theisen washers capable of dealing with 63,000 cubic ft. of gas per min., and driven by 150 h.p. motors deal so thoroughly with the gas that although it has about 3 to 4 grammes of dust per cubic metre when it comes from the furnace ; this is reduced to ·015 to ·02 grammes per cubic meter ; practically, therefore, the resultant gas is dustless.

The iron from the blast furnace is run into 20—25 ton hot metal ladles, and electricity plays no part in this stage of the operation, steam locomotives doing the haulage, though when the ladles reach the Talbot furnaces, they are handled by 40-ton six-motor electric cranes. The cogging mill is steam driven by an 18,000-h.p. three-cylinder vertical compound Richardson Westgarth engine. From the mill the ingots are fed to the bloom shears by a live roller gear, the live rollers at back and front of the mill being equipped with four 55 h.p. enclosed railway type motors.

From the bloom shears the blooms are transferred to an electrically operated charging machine, equipped with four 20 h.p. and one 10 h.p. motors ; this machine either deposits the blooms in a gas fired reheating furnace, or directly into the finishing mill, which is driven by a steam engine, practically a duplicate of that on the cogging mill. The live roller table is operated electrically as before. The finished product is then transferred to the hot saw, which is operated by a 100 h.p. shunt wound motor.

The girders, angles, &c., are now deposited on the hot bank, where they are cooled ; and subsequently passed by another line of electrically operated live rollers to the straighteners. These are by Messrs. Craig & Donald, and operated by 5, 15 and 20 h.p. motors. There are also three ending and five drilling machines operated electrically.

New Condensing Plant for the Central London Railway.—Among the recent additions to the plant at the Shepherd's Bush Power Station of the Central London Railway is a fine condensing set which forms the subject of the illustration on page 247.

The plant, which is connected directly with the new "Musgrave" engine by a branch connection to the existing exhaust main, consists of an elevated counter-current jet condenser carried on a suitable mild steel structure just outside the engine house, a set of single-stage, two-throw vertical dry air pumps, and two centrifugal water pumps driven from one high speed enclosed engine.

The exhaust steam on its way to the condenser passes through a suitable steam oil separator. The condensing water is obtained from an adjacent cooling tower, and is delivered to the condenser by one of the centrifugal pumps. The hot water drains away by gravity from the condenser to a collecting sump and is pumped from this sump to the cooling tower by the other centrifugal pump. A bye-pass connection is made between the sump and the cooling tower pond to prevent possibility of overflowing the tank whilst the delivery of the pumps is being regulated.

The plant is designed to deal with 62,000 lbs. exhaust steam per hour, and give a vacuum of 26½ in. at the condenser when supplied with cooling water at 85° F.

The condenser is built up of mild steel plates to form the body, and fitted with cast iron top and bottom covers. In the inside there are a number of trays designed so as to form four cascades of water, through each of which the steam must pass in its journey from the bottom of the condenser to the air pump suction branch which is at the top of the condenser. The cold water entering at the upper part of the condenser and falling over these trays passes in a strictly counter-current direction to the steam which enters at the bottom. The air, as already stated, is drawn from the top of the condenser and passes through a small water separator. Any entrained water is collected and is drained away to the condenser tail pipe, the dry air passing to a set of dry air pumps of the slide valve type. These pumps are of the two-crank vertical type totally enclosed, the main bearings, crank and crosshead pins, &c., being lubricated by the forced lubrication method. The oil from the various pins and bearings drains away to the bottom of the pump baseplate and passes through a suitable strainer to the oil pump exactly the same as is common with most forms of high speed engine. The air cylinders are mounted directly on the top of the pump columns, and above these are carried the high-pressure and low-pressure steam cylinders. The steam and air pistons are both fixed on to a common rod, and the pumping engine is complete with all the usual accessories.

The two centrifugal pumps are driven by an enclosed high-speed "Howden" engine, the crankshaft of which is extended at each end and drives the pumps through flanged couplings. The main exhaust pipe is built up of mild steel riveted plates, and suitable isolating valves with motor operated gear are fixed to connect to the "Musgrave" engine or existing main.

A "Venturi" meter is fitted in the circulating water discharge pipe, so that the quantity of cooling water can be easily observed and regulated by the attendant in charge.

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Iron, Steel and the Foundry.

Conducted by PERCY LONGMUIR, B.Met.

STEEL: ITS PROPERTIES AND TREATMENT.

Dry Air Blast in Steel Making.—The introduction of the Gayley dry air blast to blast furnace practice has been previously noted in this section. Experiments have recently been made in America with a view to testing the applicability of desiccated air in blowing Bessemer steel, and some interesting results have been obtained. The trials were conducted at the South Chicago works of the Illinois Steel Company, and the dry air plant supplying the blast furnaces was used. The trials extended over two days, and the average reduction in moisture of the air blown into the converters was from 5·98 to 1·39 grains of moisture per cubic foot of air. Mr. P. H. Dudley examined and tested the products, and he describes the experiments as of technical and historical importance. The results mark a considerable advance for the Bessemer process and are encouraging in the direction of increased capacity for carrying scrap and other items bearing on cost. A better control of silicon is also obtained, but the most significant feature is found in the improvement in product.

In commenting on these experiments the *Engineering and Mining Journal* states that the results shown may be of great importance in restoring confidence in the Bessemer process, and putting the converters again on a parity with open hearth furnaces as far as quality of product is concerned. The tests were on such a scale, and so carefully made that they may be accepted as fully confirming Mr. Gayley's claims for the advantage of using dry air in the converter as well as in the blast furnace. It is not impossible that in this application may be found the solution of the steel rail question, over which there has been so much controversy during the past two years. If parallel results can be obtained in continuous operation—and there is no apparent reason why they cannot—there will be no necessity to abandon the Bessemer converter and resort to the open hearth for rail steel.

American Society for Testing Materials and Steel Rails.—The steel rail question has of late attracted much attention in America, and in connection with it many ideas were ventilated at the recent meeting of the American Society for testing materials. We have just noted that desiccated air may be advanced as one remedy for removing troubles incidental to the Bessemer rail; other problems and possible solutions discussed at the meeting are noted below. Thus Dr. Henry Fay reports the results of microscopical examination of broken rails and classifies the causes of fracture under four heads: (1) unsuitable chemical composition; (2) segregation; (3) unsuitable heat treatment; (4) rolling flaws. Under (1) we have carbon which may be too high or too low; phosphorus which will produce brittleness when in excess; sulphur which, if present as iron sulphide, will make rolling difficult; slag, an indefinite term, embracing oxides or silicates or both. Sulphur, present as manganese sulphide, has generally been considered harmless, but the investigations show it to be extremely brittle and possibly a dangerous material when present in steel under certain conditions. A number of rails which had broken in the foot in crescent form, in nearly every case showed near the top surface of the fractured pieces a thin layer of apparently more brittle material extending in the direction of rolling. Each of these crescent breaks contained manganese sulphide in the form of long threads, and microscopic examination showed streaks of ferrite running parallel to the sulphide. Experiments in producing cracks showed that these usually tend to follow the manganese sulphide lines. In examining rolling flaws, only two fractures have been examined, and it would obviously be unfair to draw definite conclusions from them. However,

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it is significant that the crack developed in each case followed a streak in which manganese sulphide was embedded. The solidifying point of manganese sulphide is given as 1,162° C. As rail steel solidifies at about 1,450° C., and if rolling begins at any temperature about 1,162° C., the manganese sulphide will be liquid from the rolling temperature down to 1,162° C., and below this temperature the sulphide, being plastic, will be elongated in the direction of rolling. For this reason it is stated that the steel high in sulphur should not be rolled at too high a temperature, as the sulphur is then drawn out into a form that will ultimately lead to trouble. Dr. Fay concludes with the following suggestions. Specifications should be so drawn to limit the amount of sulphur in steel. At the present time some specifications do not even mention sulphur. The next step is to allow the metal to stand a longer time after the addition of ferro-manganese. The specific gravity of manganese sulphide is 3·966, and that of steel 6·82, therefore if given sufficient time the sulphide should rise to the surface and enter the slag. Usually the time interval between adding the ferro-manganese and pouring the ingots is very short. Dr. Fay concludes by stating that if it is not permissible to start with an initially low sulphur, or to allow a sufficient time interval for the removal of the manganese sulphide, resort must be had to electric refining of molten metal by means of basic slag.

Rail Tests at Watertown Arsenal.—Mr. J. E. Howard reported some of the tests now in progress at the Arsenal, and in discussing service conditions which lead to failure noted the following points. Cold straightening of rails necessarily impairs the elastic limit of the metal and permanent sets, although of limited extent, may be expected to develop under comparatively low loads. The heating of the surface of the rail head caused by the slipping of locomotive driving wheels is given as another cause which promotes rupture. The heating of surface metal is followed by rapid cooling, and hardening follows. There is also a change from a state of internal compression existing while the metal is hot, to one of internal tension when the surface metal becomes cold, resulting in the formation of cracks in the steel, minute fissures forming in the head which are a menace to the integrity of the rail as a whole.

Rail Failures.—Mr. M. H. Wickhorst, in discussing failures takes as a sub-title, "Mashed and Split Heads." These failures first show by the development of a dark streak along the head of the rail from several feet to several yards long. At the same time the head starts to sag down on one or perhaps both sides spreading somewhat during this sagging. As an illustration a rail having approximately seventy days service is quoted. The marking indicated this rail to be the top one of the ingot. It was laid as the outer rail of a three degree curve and was the seventh rail from the beginning of the curve. The rail was removed on account of a black streak showing on the head of the rail, and in addition to this black streak there could be detected by eye a sunken portion on the outside part of the head about two or three feet from one end and extending over a length of six or seven feet. Sections were taken from the rail where it seemed to be in the worst condition and from a position where it was apparently in good condition. These are denoted *A* and *B* respectively, and drillings from them gave the following analyses.

	Carbon per cent.	Phosphorus per cent.	Sulphur per cent.	Manganese per cent.
A Head...	0·51	0·082	0·060	1·24
A Web ...	0·81	0·117	0·152	1·38
B Head...	0·56	0·119	0·076	1·41
B Web ...	0·64	0·163	0·114	1·55

Considerable segregation is thus shown in carbon, phosphorus and sulphur in both cases. From the work done, splitting of the head may be probably explained as follows. The load comes on the head of the rail more or less to one side due to the wear of the tread of the wheel or canting of the rail, which introduces transverse, tensile stresses in the head of the rail, being greatest at the top. On account of the bad segregation and in consequence of the weak condition of the metal, the material is unable to withstand the internal tensile stress, and a crack developes internally, which gradually lengthens until it finally breaks through on the under side of the head where it joins the web. The top surface of the head being of normal composition for a depth of about ¼ in., and having the effect of rolling, is in good physical condition, and it flows instead of developing a crack, which explains why the crack starts internally. Other rails which have failed by reason of the heads splitting have been examined and marked segregation found. This segregation occurs chiefly in the top rail of the ingots, where there is also more or less sponginess of structure. Split heads—that is, cracks which develop after the rails are put into service—are probably due to this

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condition of segregation and sponginess. Pipes may exist in the rail as rolled, but probably the great majority of failures called pipes by trackmen are really splits occurring as described.

The Rail Situation.—According to Mr. E. F. Kenney, up to about ten years ago there was practically no rail problem. Breakages were comparatively slight, and wear, except in sharp curves, was such as to cause no uneasiness. The factor of safety was large enough to take care of unusual conditions, but the advent of heavy wheel loads and greater tonnage and speed of the last few years have increased the stresses and shock in the rail. Moreover, the difficulty of maintaining a good track has increased, and as the condition of the road bed as to line surface, &c., has an immediate effect in the stresses and shock in the rail, these elements, combined with the direct effect on the rail from the increased loads and speed, have so increased the rails' work that the factor of safety has vanished. In almost any engineering structure an increase in load is met by larger sections and stronger members, but there seems to be opposition to an increase in the amount of metal in a rail. Whilst various reasons are given for this attitude none of them are convincing. As the average cost of rail on American roads is only about seven per cent. of the total maintenance charges, and as it is well known that the cost of maintaining track laid with 100 lb. rails is decidedly less than that laid with 85 or 70 lbs., it seems quite probable that the adoption of much heavier rail sections than those used to-day would be distinctly an economy because of the reduction of the cost of maintaining the track. Aside from economy it would unquestionably be an advance on the side of safety. As an illustration of the failures due to split heads the following figures, from an official source, are quoted. The lines represent roads having heavy traffic, *A* having the heaviest tonnage in the country. *A* uses a deep headed rail, whilst *B* and *C* use shallow headed rails. The number of 100 lb. rails removed from the track in one year per 1000 tons rolled is 0·66 for road *A* and 12·59 for *C*. The number of 85 lb. rails removed from track in one year per 1,000 tons rolled is 0·59 for *A*; 6·02 for *B*; and 8·08 for *C*. The percentage of failures was ten to twenty times as great for *B* and *C* as for *A*, and of these failures 90 per cent. were in the head, namely, splitting, often spoken of as piping, while this type of failure was almost unknown on road *A*. The shallow head is an element of weakness which must be avoided if we are to escape this type of failure, and the necessary stiffness should be provided, not by spreading the metal out so thin as to weaken the head and base of the rail, but by the addition of enough metal to furnish the required girder strength without weakening the section in its details. Touching on open hearth rails, the author states that in some quarters the term "open hearth" is regarded as a talisman which will cure all troubles. Some rails of open hearth steel have given excellent service, and others have yielded anything but good results. Some years ago the author suggested the use of high carbon rails, phosphorus being kept low in order to permit of higher carbon. The Pennsylvania Railroad made a trial lot of rails of from 0·80 to 0·90 per cent. carbon and less than 0·02 per cent. phosphorus. These rails gave excellent service, not because they were open hearth rails, but because the low phosphorus permitted the use of sufficiently high carbon in order to make them wear well. It is impossible to use this content of carbon in open hearth steel much higher in phosphorus and open hearth steel of lower carbon will not give the wear shown by these rails.

In regard to discard, the usual method of cropping at the shears does not always indicate when the piped portion has been entirely removed. This has led to the suggestion of heavy discards, but in order to obviate the heavy waste accompanying discards of, say, 25 per cent., the following plan has been adopted. The crop end from the top of each ingot is tested to destruction, and if piping is shown all the top rails from that heat are rejected. This practically means that about 30 per cent. will be discarded from all heats which show piping, while those which do not show piping are cropped only the usual amount. The Cambria Steel Co. by following this plan have found that of the heats showing pipes in the drop test piece when tested to destruction, 60 per cent. contained pipes so short that they were confined entirely to the crop end. Of the remaining 40 per cent. which extended into the top rail, the piping was as shown in the following table:—

EXTENT OF PIPING IN RAILS.

40	showed pipe extending more than	1 ft.	but less than	4 ft.	
26	"	"	"	7 ft.	
20	"	"	"	10 ft.	
16	"	"	"	13 ft.	
16	"	"	"	16 ft.	
10	"	"	"	19 ft.	
10	"	"	"	22 ft.	
10	"	"	"	25 ft.	
8	"	"	"	28 ft.	

6 extended all the way through (very slight).

The Engineer's Book-shelf

The Metallurgy of Iron and Steel.

By Bradley Stoughton, Ph.B., B.S. (New York: The Hill Publishing Co.) Pp. 509. **$3·00.**

In his preface the author states "the purpose of this book is to serve as a text book, not only for college work, but for civil, mechanical, electrical, metallurgical, mining engineers, architects, and for those engaged in work allied to engineering or metallurgy." The purpose is most commendable and the author has certainly endeavoured to cover within one volume the whole of the metallurgy of iron and steel. From a literary point of view this endeavour is successful and a very readable compilation results. However, students of metallurgy and members of the professions enumerated above require in addition to literary grace some underlying facts which will give guidance either in studies or occupation. From this materialistic point of view the book is disappointing, and the author has by no means reached the high level of technical accuracy so characteristic of many American text books on metallurgy.* We do not refer to purely controversial matters, such as the constitution of steel or metallographical features, but to everyday common facts, on which agreement is universal. For example on page 70 one sentence reads:—

"The Swedish-Lancashire process is known as the 'Walloon process,' and is used in Sweden for making bar iron from the very pure pig iron reduced from Dannemora iron ore."

Even the most elementary student should be acquainted with the fact that Lancashire and Walloon represent two distinct processes, both at work to-day in Sweden. Apart from special branding, bar iron as received in Sheffield to-day is known either as a Lancashire or Walloon product, and the difference in cost between the two is represented by several shillings per cwt.

Still on page 70, Sheffield steel makers are described:—"as paying a high price for Walloon bar iron, in the belief that it has a certain intangible 'body' not contained in wrought iron from any other process. It is probable, however, that this body is wholly imaginary."

Practical men know that it is "body" which differentiates Lancashire from Walloon hearth, and commercial men recognise it in the difference in cost between the two. Instead of body being an imaginary property it is one admitting of most ready demonstration, and although as yet theoretical metallurgists have offered no explanation, such explanation will come with advancing knowledge.

Similar features mar an otherwise good description of the crucible process, thus page 87; "in Sheffield coke melting holes . . . are almost universally used," contains just sufficient truth to justify the statement. At the same time gas fired crucible furnaces are not unknown in Sheffield, and even in this conservative centre the electric furnace is receiving earnest consideration.

Referring to the "killing" fire, the author states:—(page 91).

"Some have suggested that the gas contained in the steel is eliminated from it during this time, but Professor Howe's suggestion, that the principal effect of the killing is to cause the steel to absorb silicon, becoming sound on this account, is the more generally accepted one. The amount of silicon in the final steel will vary greatly, but will average perhaps from 0·10 to 0·50 per cent."

These observations are not supported by actual experience, and at any rate, as far as Sheffield crucible steel is concerned, silicons do not vary greatly; as a matter of fact the variation is extremely slight. Records of over two thousand crucible ingots produced in the regular way of commerce show extremely little silicon variation, and the average figure is 0·154 per cent. Silicon is, of course, sometimes added as a special element, but this is a feature quite distinct from the silicon introduced by the killing fire.

It is, perhaps, hardly necessary to note further mis-statements of kindred nature to the foregoing. Possibly these points may appear trifling, but they are such that if accepted in faith by the student would inevitably lead to failure in any examination.

As a whole the work is well illustrated, but it is hard to see what purpose the weird blotches, Figs. 44 to 51, can possibly serve. The last, Fig. 51, is described as the rolling of puddled bar: apart from the description it is hard to distinguish anything. Throughout the photo-micrographs are extremely poor, and in this respect it is somewhat amusing to note that in

* For example, Campbell's "Manufacture and Properties of Iron and Steel," Peters' "Principles of Copper Smelting," &c.

one portion of the book, the author says (page 451):—

"Never form an opinion upon a specimen that retains scratches or polishing marks," notwithstanding the fact that some of his own illustrations show scratches.

The Electric Furnace, its Evolution, Theory and Practice. By ALFRED STANSFIELD, A.R.S.M., D.Sc. (New York: The Hill Publishing Co. Toronto: *The Canadian Engineer.*) Pp. 211.

Within 194 pages of text, aided by fifty-two illustrations, Professor Stansfield gives a clear review of the development of the electric furnace, its present position and future possibilities. The ground is fully and completely covered in the minimum number of words, in fact it would be difficult to find an unnecessary word in the whole of the text. In our opinion the brevity and extreme clearness of the book form quite as distinct a feature as its technical excellence. Technically the work is admirable, and in view of the looming importance of electro-thermic methods no metallurgist can afford to overlook Dr. Stansfield's well considered remarks. In place of mere description the author has adopted the wiser plan of dissection: therefore the reader instead of wading through a series of processes as described by their inventors, has a series of suggestive comments and observations embodying in each case "the reason why." Thus the chapter headings give a good index of the method followed, and these are:—

History of the electric furnace; Description and classification of electric furnaces; efficiency of electric and other furnaces and relative cost of electrical and fuel heat; Electric furnace design, construction and operation; Production of iron and steel; Other uses of electric furnaces, and finally, Future developments of the Electric furnace.

The book is not only worth buying, but is worth careful reading and digestion, for the matter is reliable.

The Metallurgy of Common Metals. By L. S. AUSTIN. (San Francisco: The Mining and Scientific Press.) Pp. 407.

This book is of a somewhat general character, and the metals included are gold, silver, iron, copper, lead and zinc. Before passing on to a consideration of these metals, the author gives an excellent outline of metallurgical preliminaries and a really good chapter on roasting. The metals enumerated above are then dealt with in separate sections, and the three on gold, silver and copper certainly show the author at his best. The section on zinc is remarkably short, and is, in fact, simply sufficient to whet the appetite for more. The section on iron is limited to the production of pig-iron, and it is perhaps a pity that the author has not included an outline of the further treatment of pig-iron. The concluding sections represent a special study of refining and commercial conditions. The latter, though intended for American readers, is not without value to a British audience. In fine, the book does not pretend to exhaustive detail, but rather gives a salient description of the metallurgy of the more familiar metals.

The Blacksmith's Guide. By J. F. SALLOWS. Pp. 148. Appendix and index. Cloth, **$1.50**; leather, **$2.00.** (Brattleboro Vt.: The Technical Press.)

Within very small compass Mr. Sallows gives most pertinent advice to the blacksmith, and much information of value to the general mechanic. Commencing with the interpretation of a drawing, the author rapidly but clearly reviews various aspects of forging. Machine forging and tool forging are logically treated in two chapters remarkably free from padding. Two chapters on hardening and tempering and case hardening are especially valuable and most practical. Other chapters treat of high speed steel, brazing, general smithing, and in the appendix coloured heating and tempering charts are reproduced.

The book is the work of a practical man, and whatever literary grace may be lacking is fully made up in the reliable and practical value of the information.

Laboratoriumsbuch für den Eisenhüttenchemiker. By MAX ORTHEY. (Halle A. S.: Wilhelm Knapp.) Pp. 49. Price, **Marks 1.80.**

This handy little work represents Vol. I. of a series of laboratory books to be devoted to the chemical and allied industries. The series are being produced under the general editorship of Mr. L. Max Wohlgemuth. The present work deals very effectively with the routine analysis of an iron and steel works laboratory. The methods given are reliable, and special elements receive their due share of attention. Starting with the analysis of ores, the author passes on to methods for the analysis of iron and steel, slags, refractory materials, fuels and gases. The text is commendably brief, and the work is highly practical in character.

Modern Practice in Mining. *Volt.* Coal, Its Occurrence, Value and Methods of Boring. By R. A. S. REDMAYNE, M.Sc., M.Inst.C.E., M.Inst.M.E. (London: Longmans, Green & Co., 39, Paternoster Row. Pp. 196 + vi. Price **6s.** net.

GENERAL REVIEW

LEADING ARTICLES OF THE MONTH—CURRENT EVENTS—TECHNICAL INFORMATION FROM ALL SOURCES.

Water Brakes for Testing Steam Turbines.—In the testing shop of the Westinghouse Machine Company, Pittsburg, the turbines are tested under the desired condition of operation. The determination of the brake horse power developed is made by means of a water-brake consisting of a casing with an internally notched periphery in which a rotor, also with notches in its periphery, rotates. The rotor has two heavy flanges, one on each side, which extend both inside and outside of the rim of the wheel.

As the energy absorbed by the brake is converted into heat by the friction of the water shock, and eddies formed by the water thrown from the impeller striking the notches of the stationary portion, it is necessary to keep the brake constantly supplied with cold water, or the water would be soon evaporated.

Water is supplied to the brake through a pipe which extends through the casing and delivers the water to the inside of the rotor, the centrifugal force distributing the water evenly around the periphery of the inside of the rim, for which purpose the internal flanges are provided. The water from the inside of the wheel then flows outward to the exterior of the wheel through holes bored through the partitions of the external part to the interior of the rotor.

The water thrown from the wheel strikes the projections of the stator at very high velocity, loses its kinetic energy by transforming it into heat, falls back on to the rotor, and is again thrown against the stator, this process being repeated until the heat generated by impact and friction brings the water to the boiling point and evaporates it.

These water brakes are, says *Power*, of enormous capacity in comparison with their size. A brake of the smallest size, having a diameter of but 22 in. and a face of 8 in., is capable of absorbing from 1,800 to 2,000 boiler h.p. at 3,600 r.p.m. The largest used at the Westinghouse plant is capable of absorbing about 10,000 boiler h.p. at 750 r.p.m, or considerably more at a higher speed. The eroding power of hot water projected against a metallic surface at high velocity is very great, so the stationary liner and the material of the rotor are of cast steel. The capacity of the brake decreases about 30 per cent. after 240 hours' service at full load, when it is necessary to turn down the rotor about ¼ in., and fit a new steel liner on the stator.

The Belt Conveyor.—Some interesting points connected with the design and operation of belt conveyors were brought out in a paper on the subject by Mr. C. Baldwin, before a recent meeting of the Am. S. Mech. E. The first point is that the belt conveyor has one great advantage over other types, in that it may be driven from any point in its length. Pulleys, the author states, should have heavy arms and rims with extra high crowns, and they should be secured to their shafts by both keys and set screws. Multiple pulley drives are now being used on the longer conveyors with most satisfactory results. In this type of drive, the belt is passed over two or more pulleys geared together so they turn at the same speed. This makes it possible to use smaller pulleys, thereby simplifying the speed reduction from the motor or engine. The belt may also be run as slack as desired, provided there is some means of keeping the belt in contact with the second drive pulley, by allowing it to sag or using a weighted take-up. A belt under great tension is hard to train, therefore the conveyor with multiple pulley drive may be more easily adjusted and operated.

Pulleys of small diameter should be avoided on heavy belts, otherwise the constant bending when under heavy stress will cause the friction to lose its hold and destroy the belts.

Material should always be delivered to the belt in the direction of belt travel and, as nearly as possible, at the same speed. The author favours the shaking feeder, consisting of an inclined pan set under the bin opening at such an angle that it stops the flow when stationary. When given a reciprocating motion by a crank and connecting rod the material is moved along the pan to the belt. By varying the length of stroke and inclination of the pan the amount of material delivered may be absolutely regulated.

The following table gives the capacity, maximum size of lumps, and advisable speed for the different width of belts.

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TABLE I.—BELT CAPACITY AND SPEED.

Width of belt, ins.	Maximum size of pieces, ins.	Capacity in cubic feet per hour at a belt speed of 100 ft. per min.	Capacity in tons per hour, at a belt speed of 100 ft. per min., material weighing 100 lbs. per cubic foot.	Maximum advisable speed in feet per minute.	Capacity in cubic feet at the maximum advisable belt speed.	Capacity in tons per hour at the maximum advisable belt speed, material weighing 100 lbs. per cubic foot.
12	2	460	23	300	1,380	69
14	2½	630	31	300	1,890	94
16	3	820	41	300	2,460	123
18	4	1,040	52	350	3,640	182
20	5	1,280	64	350	4,480	224
22	6	1,550	78	400	6,200	310
24	8	1,850	93	400	7,400	370
26	9	2,180	110	450	9,810	490
28	12	2,500	125	450	11,250	563
30	14	2,900	145	450	13,050	653
32	15	3,300	165	500	16,500	825
34	16	3,700	185	500	18,500	925
36	18	4,200	210	500	21,000	1,050
38	19	4,600	230	550	25,300	1,265
40	20	5,100	255	550	28,050	1,402
42	20	5,600	280	550	30,800	1,540
44	22	6,200	310	600	37,200	1,860
46	22	6,800	340	600	40,800	2,040
48	24	7,400	370	600	44,400	2,220

The power required to drive a belt conveyor should always be calculated for the full capacity at the chosen speed, as follows —

C = Power constant from Table II.,
T = Load in tons per hour,
L = Length of conveyor between centres in feet,
H = Vertical height in feet that material is lifted,
S = Belt speed in feet per minute,
B = Width of belt in inches.

TABLE II.—POWER REQUIRED FOR GIVEN LOAD.

Width of belt.	C for material weighing from 25 lb. to 75 lb. per cubic foot.	C for material weighing from 75 lb. to 125 lb. per cubic foot.	H.P. required for each movable or fixed tripper.	Plies of belt.	
				Minimum.	Maximum.
12	·234	·147	½	3	4
14	·226	·143	¾	3	4
16	·220	·140	¾	4	5
18	·209	·138	1	4	5
20	·205	·136	1¼	4	6
22	·199	·133	1½	5	6
24	·195	·131	1½	5	7
26	·187	·127	2	5	7
28	·175	·121	2¼	5	8
30	·167	·117	2½	6	8
32	·163	·115	2¾	6	9
34	·161	·114	3	6	10
36	·157	·112	3¼	6	10

For level conveyors,

$$\text{H. P.} = \frac{C \times T \times L}{1{,}000}$$

For inclined conveyors,

$$\text{H. P.} = \frac{C \times T \times L}{1{,}000} + \frac{T \times H}{1{,}000}$$

Add for each movable or fixed tripper, horse power in column 3 of table. Add 20 per cent. to horse power for each conveyor under 50 ft. in length. Add 10 per cent. to horse power for each conveyor between 50 ft. and 100 ft. in length.

The above figures do not include gear friction, should the conveyor be driven by gears.

With the load known, choose from the capacity table the proper width of belt and proper speed. With the horse power and the speed known, the stress in the belt may be obtained by the following formula in order to find the proper number of plies. Stress in belt in pounds per in. in width =

$$\frac{\text{H. P.} \times 33{,}000}{S \times B}$$

With this value known, the number of plies may be determined, using 20 lb. per in. per ply as the maximum. The two latter columns of Table II. give the maximum and minimum advisable plies of the different widths of belt. Belts between these limits will trough properly and will be stiff enough to support the load. The maximum number of plies determines the maximum length for each width of conveyor.

Concrete-Steel Breakwater Caissons. — The *Engineering Record* publishes an account of a novel breakwater now under construction, the principle feature of which is the employment of floatable concrete-steel caissons, each 24 ft. long, 15 ft. wide and 12 ft. 4 in. high, designed to be sunk in juxtaposition along the line of the breakwater and then filled with broken stone and concrete. The caissons are being constructed on ways from which they are launched into the water, and then towed about twelve miles to the site of the breakwater.

Each caisson weighs about 120 tons and floats after launching about three-fourths submerged. The caissons are roughly water-proofed with a thin grout containing lye and alum applied to the exterior. Most of the caissons are without perceptible leakage; that is to say, without greater leakage than is carried off by evaporation. A few require a few minutes' pumping at intervals of several days.

The ways under each caisson consist of 12 by 12 in. stringers, supported on piling. The slope of the ways is one in ten and they terminate about 5 ft. under water. No force is required to start the caissons down the ways. There are three sets of ways, side by side, each one consisting of three stringers. A caisson is made every three days. With three sets of ways this involves the launching of a caisson when it is from nine to ten days old. The actual placing of the concrete after the steel and forms are in place requires about seven hours.

Immunity from Rusting of Reinforcing Steel in Concrete.*—The much-mooted question whether the steel reinforcement in beams of reinforced concrete is in danger of rusting by the entrance of air and moisture through the inevitable tension cracks has recently been studied by Mr. E. Probst in tests made at the Prussian Royal Testing Institution at Gross-Lichterfelde West, Berlin, Germany. They give practically the first experimental showing that the ordinary tension cracks (occurring within the limits of permissible loading) do *not* permit the atmospheric corroding influences to affect the steel; they indicate that rusting by entrance of air and moisture is to be apprehended in cases where the stress in the steel has passed the elastic limit and in consequence has opened relatively wide cracks, but not in cases where the stresses are well below this. Tests of thirty-two beams by an accelerated rusting test showed no rusting in twenty-seven cases in all of which the load was such as to stress the steel to from 18,000 to 35,000 lbs. per sq. in. In five tests, where the load was higher and the steel was stressed to values of 35,000 to 44,000 lbs. per sq. in., rusting resulted.

The Effect of Superheated Steam on Hydro-Carbon Cylinder Oils.—A series of experiments have been recently undertaken by C. W. Worrall and J. E. Southcombe with a view to throwing further light on the problem of cylinder lubrication. The results have been published in the Journal of the Society of Chemical Industry.† They may be summarised as follows: No chemical change of a hydro-carbon cylinder oil takes place in a cylinder using steam which is not heated up to 750° F. The deposits consist chiefly of oxide of iron, which is formed independently of the oil. The adhesion of the oxide producing deposits depends upon the pitchy constituent in the oil and the completeness of distillation. The oil is fractionated by the steam, the shape of the cylinder and adjacent parts, and the temperature influencing the quantity of pitchy matter remaining behind.

The effect of superheated steam on lubricating oil is to fractionate it by distillation without decomposition, so long as the temperature is below 750° F. The lowest boiling fractions probably pass through the engines to the second or third cylinder or on to the hotwell, while the higher boiling fractions lubricate the first cylinder, and the highest, *i.e.*, the residue, if any, deposits in the ports and passages of the engine and collects the oxide of iron which may be carried by the steam from the superheater.

The exact behaviour of a given oil in a steam engine depends upon the temperatures in the various parts through which it passes. Although the distillation of an oil primarily depends upon the temperature, the purity of the fractions depends to a large extent upon the shape of the vessel in which distillation takes place. This shape should be such as to cause the rising vapour to come into contact with the liquid; this is usually accomplished by causing some of the vapour to condense and drop back into the liquid, and thus come into contact with the other vapour as it ascends. This action might take place in the steam engine if a bend or pocket were formed in the steam pipe close to the point of inlet of the oil, and so produce eddies in the current of steam and cause the oil vapour to come into contact with the sides of the pipe or valve, where some of the vapour would probably condense. In order to lubricate the cylinder, the oil vapour must condense on the cylinder walls; this would take place owing to the fall of temperature to which the cylinder is subject during the expansion of the steam. The present investigation shows the conditions which must be considered in selecting an oil, and suggests the possibility of producing an oil to suit any given set of conditions.

Erecting the Construction Footways of the Manhattan Bridge.—The work of erecting the construction footways from which the cables of the new Manhattan Bridge will be strung is practically completed. A recent issue of the *Scientific American* contains some interesting details of this structure from which we gather the following: The floor of the bridge will be hung from four large cables, each 21½ in. diameter, measured on the wires without the wrapping or sheathing. Each cable will contain 9,472 galvanized wires 0·19 in. in diameter. The total length of single wire in all of the four cables together will be 23,100 miles. The wire will have an ultimate strength of 215,000 lbs. to the sq. in.; and the main cables will be subjected to a working load of 60,000 lbs., and a congested load of 73,000 lbs. to the sq. in. The side spans of the bridge will be 725 ft., and the central span 1,470 ft. in length. The total weight of steel in place, when the structure is completed, will be 42,000 tons. The suspended roadway will consist of four trusses, each 24 ft. in depth centre to centre of chords. Each pair of trusses will be spaced 28 ft. apart, and there will be a spacing of 40 ft. between the inside trusses of each pair. Provision will be made for four sets of rails, two of them on the upper, and two on the lower deck of the trusses; and two footways each 10 ft. wide will be carried on the outside of the bridge upon cantilever extensions on the floor beams. The central roadway for vehicles, 35 ft. in width, will occupy the centre of the bridge at the level of the lower deck of the trusses.

The weight of the four great cables in their completed condition will be 6,300 tons. Each cable will be built up of thirty-seven strands, each 3½ in. in diameter, each strand consisting of 256 wires. At the anchorages the strands will pass around sheaves, held by the massive anchorage I-beams which are already in place, firmly imbedded in the masonry of the anchorage. In laying the cables, the wire will be drawn to and fro across the bridge until the necessary 256 wires

* *Engineering Record*, Vol. 59, No. 20.
† April 16, 1908.

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have been placed, to form a strand. At each anchorage, and on a series of wooden trestles, two on each end span and five on the main span, erected on the working platform, are a series of sheaves or pulleys, on which the wire in making up a strand is laid. There are four of these sheaves at each anchorage and on each trestle, so that four strands may be in the process of assembling at the same time, two being woven a few feet to the right of the main cable, and two a few feet to the left thereof. As soon as a strand is completed, it will be lifted out of its set of sheaves and transferred to the main saddles, of which there is one for each cable at the top of the towers, and one at each abutment.

When the thirty-seven strands of a cable have been laid, and placed in the saddles, the whole mass will be clamped into true circular form, and the weather protection, in the form of a sheathing of steel plates, will be laid on with joints overlapping so as to shed all water and protect the wires from the weather. At intervals of 18 ft. heavy clamps will be placed round the cables, and from these will be hung the 1¾-in. suspenders to which the floor of the bridge with its trusses and platforms will be suspended. The suspenders will be made largely from the wire ropes composing the erecting platforms, and as there is about 48,000 feet of these, they will go far to supply the necessary amount.

A Rapid Gear-tooth Rounding Device.—Various devices have appeared from time to time for rounding or chamfering the teeth of gear wheels such as are used for automobile speed varying purposes. These range from the attachment worked entirely by hand to the specially constructed machine, fully automatic, but only profitable in shops where the output is exceptionally large.

Figs. 1—3* show an attachment for use in conjunction with a Brown & Sharpe, or similarly designed gear cutting machine, thus rendering it entirely automatic in its action by making use of the indexing and traversing mechanism. In addition to this there are two other features which the writer has not seen embodied in any other appliance of this character, viz.: The teeth may be rounded after cutting the gear, and before dismounting it, thus saving the time required for setting-up on another machine; also a circular cutter is used instead of the usual end-mill.

A casting *B* is planed to fit one of the ways of the machine to which it is attached by the bolt shown in Fig. 1; the slot in the base provides for longitudinal adjustment and vees are turned on the upper face to correspond with those in slide *S*. The circular bosses in *S* and *C* are machined on the faces and bored to fit the centre pin on which the pulley *P* and spur wheel *W* are free to revolve, the cutter *A* being driven by means of the pinion *V* in mesh with *W* and keyed to the end of cutter spindle, while *P* is driven from a light countershaft directly above it.

F is a bracket attached to the cutter slide *M* of the machine and *R* a link connecting this slide with *S* of the attachment. Having cut a gear with cutter *K*, the indexing worm wheel of the machine is first rotated an amount sufficient to bring the teeth into the correct position for rounding, the slide *M* is then run well back, and the attachment fixed to the machine ways with bolt shown in Fig. 1. *R* is then connected to *F* by means of pin *O*, so that the reciprocating movement of *M* will cause the cutter *A* to follow a circular path, the radius of which may be varied by different pitch gears by rotating *C* about the centre pin and fixing in the desired position with the two bolts shown on the right of Fig. 3. For most gears a travel of 2 in. on slide *M* is sufficient when rounding teeth, and as provision is generally made on these machines for a cutter feed of upwards of 50 in. per min. with accelerated return, it will be readily seen that gears may be machined by this method in an incredibly short time.

H. G. WILLIAMS.

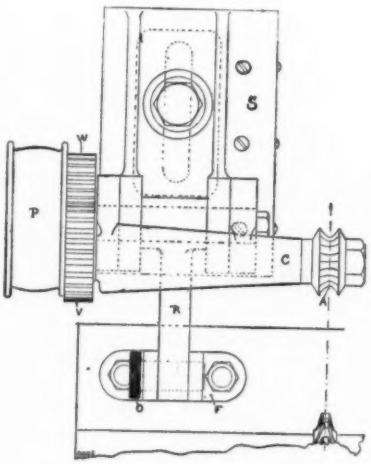


FIG. 3.

* For Figs. 1 and 2 see page 238.

Machinery, Appliances and Processes.

The Editor invites advance particulars, drawings, blue prints, photographs, and any data that will enable him to publish an adequate description in these columns of any new work, machinery, or installation, possessing special features of interest. The cost of publication and engraving is borne by us, and no compensation is expected. In the endeavour to produce a really high-class and technically valuable machinery section the Editor seeks the co-operation of engineers and manufacturers.

Steam Motor Vacuum Cesspool Exhauster.

Cesspool emptiers on the vacuum system are now making considerable headway, owing to the great advantages their adoption secures. Their method of working depends on the creation of a vacuum in a cylindrical tank, whereupon the sewage is drawn up through suction piping into the tank, and seeing that the efficiency of the arrangement is dependent on air-tight conditions prevailing, there is an entire absence of nuisance. A steam motor driven appliance of this description has just been purchased by the Epsom Rural District Council from Messrs. Merryweather & Sons, of London, and is shown in our illustration.

The frame is of channel steel, with strong cross-stretchers, mounted on four springs, steel axles, and heavy artillery wheels, those in the rear having tyres 10 in. wide, so as to be suitable for running over soft ground. The boiler is of the firm's quick steam raising type, fitted with curved and inclined water tubes, and is lagged with felt

STEAM MOTOR VACUUM CESSPOOL EXHAUSTER.

XUM

and planished steel. The engine is of the double-cylinder vertical type, with transmission giving two speeds of five miles and one mile per hour, and drives the rear wheels by means of steel roller chains. The steering gear is of the divided-axle type, operated by a vertical screw spindle, with necessary levers and rods. The driver's seat, which is situated between the engine and boiler, forms the lid of a box holding tools, and is protected from the weather by a light galvanised steel awning. Coal bunkers are fitted on the frame on each side of the boiler, and capacious water tanks are arranged under the frame. The vacuum tank, which has a capacity of about 750 gallons, is constructed of galvanised steel. It is fitted with a vacuum gauge and a gauge to show the depth of the contents. A man-hole is provided for cleaning. At the rear is a wheel-valve for opening and closing the suction inlet, and there is also a valve with a large delivery bend for emptying. The suction-pipe, which is 4 in. internal diameter, and is of two kinds—flexible india-rubber and light galvanised steel—is fitted with gun-metal screws for connecting together, and is carried in strong brackets at each side of the tank.

The apparatus will be used in the higher parts of Epsom Rural District, where drainage systems are not in vogue. It has been specially constructed to meet the requirements of the neighbourhood. Several narrow country lanes will have to be traversed, and the over-all width has been kept down to sufficiently moderate dimensions to admit of this being done. With regard to the method of working, a high vacuum is first created in the tank, this vacuum being produced by the agency of a steam ejector. All valves are then closed, and the necessary length of suction piping is connected to the tank at one end, the other end being placed down the cesspool. The suction valve is then opened, and the contents of the cesspool are at once drawn up into the tank.

Whilst from a sanitary point of view, this apparatus shows great advantages over old methods of dealing with cesspools, it also effects considerable economy in the cost of working. The Rural District Council of Romford, Essex, where a similar plant has been in active service for the past three years, has, we are informed, secured a saving of no less than 80 per cent. on the old method with horsed vans. It may be mentioned that with the Romford exhauster the vacuum is created by means of an air pump, instead of the steam ejector as fitted on the machine under notice.

The "Bandy" Single-Phase Alternating-Current Motor.

It is hardly necessary for us to point out the demand that has existed, in connection with the driving of textile printing and paper-making machinery, machine tools and lifts, for a motor which is capable of developing a high starting torque and at the same time of having its speed varied at any point between zero and full speed, all at high points of efficiency. As an extension to the well-known variable speed electric motor equipment associated with the name of Messrs. Bergtheil & Young, Ltd., of 12, Camomile Street, E.C., a motor has been introduced by them fulfilling the requisites and capable, it is claimed, of developing a starting torque up to 2½ times the full running torque. It is also claimed that the current consumption when developing a heavy starting torque is less than that required by a series-wound continuous-current motor, and, as in the case of this machine, its speed is capable of the same regulation. With fixed point the speed is proportionate to the torque required.

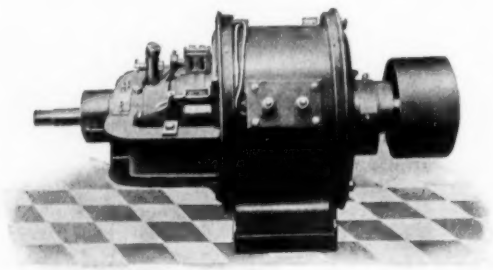


FIG. 1.

Referring to the illustrations, different forms of assembly and speed controlling devices are shown, the purpose and characteristics of which are as follows.

Fig. 1 illustrates the machine assembled as an ordinary variable speed power motor with the same characteristics as a series-wound continuous-current machine. It has its speed

regulated and direction of rotation controlled by rocking the brush gear, or alternatively its speed varied only by an ordinary rheostat put in series with its stator winding. Any suitable mechanical coupling gear may be attached to the brush rocker so that the necessary convenient control be obtained.

Fig. 2 shows the motor with brush rocking gear coupled to an automatic centrifugal governor, switch, and controlling shaft, the form of assembly supplied where it is desired to control the speed of the motor automatically, as for electric lifts and similar drives. This condition is obtained by the centrifugal governor automatically throwing the brush gear into a position which limits the speed of the motor, the maximum speed being determined within a wide range by adjustment of the spring tension anchored to the housing lug on the top of the yoke.

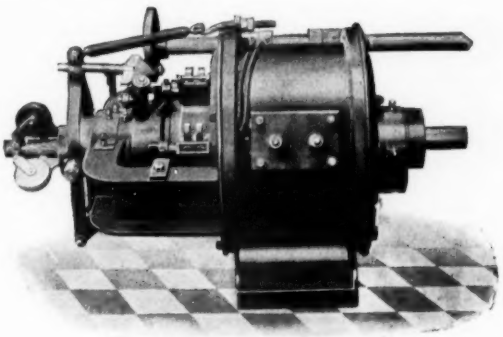


FIG 2.

This motor is primarily controlled by turning the controlling shaft through an arc of, say, 150 deg. in either direction to and from a neutral point, the direction of rotation of the motor being the opposite to that in which the gear is rocked from the neutral point.

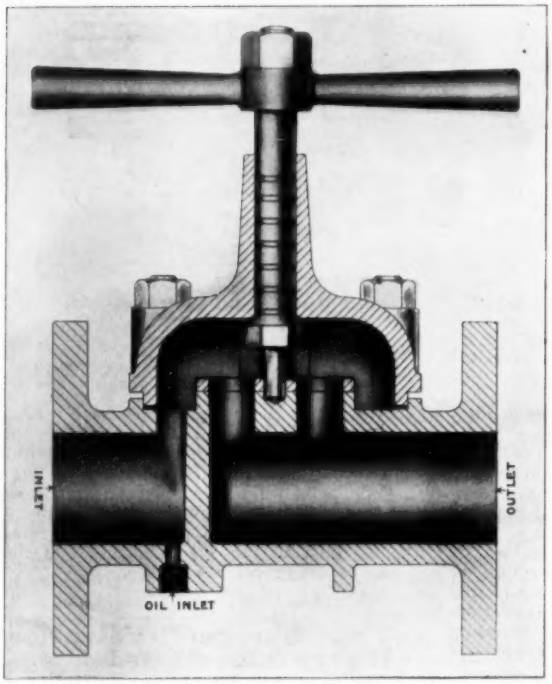
We are informed that tests taken on a 5 h.p. motor at 900 r.p.m. on a single-phase circuit of 200 volts 50 periods, showed the machine to have a full-load efficiency of 80 per cent. and a half-load efficiency of 72 per cent., a power factor of ·85, and further that a starting torque of one pound per 100 volt-amperes at 1 ft. radius was developed between normal starting torque and 2½ times full-load torque. The motor may be switched straight into circuit without a controller or starter, and 1½ times full-load torque will be developed with approximately full-load current, and twice full-load torque with 1¼ to 1½ times full-load current, according to the speed and size of the motor and general conditions.

The "Sheppee" Valve for Highly Superheated Steam.

The valve forming the subject of the accompanying illustrations has been designed for use with highly superheated steam, and to that end stuffing boxes and glands have been entirely dispensed with. The body and top cover of the valve are made of iron, and a central spindle of steel passing through the top cover has its inner end pivoted in the valve case seating, and passes through a circular valve which is free to turn on the spindle as a centre. The steam supply is admitted outside the surface of the valve seat, which is therefore under pressure.

VIEW OF COMPONENT PARTS OF THE "SHEPPEE" VALVE.

The valve is loose on the central spindle in order to keep



SECTION OF "SHEPPEE" VALVE.

the faces of the valve and seating steam tight; projections on a part of the central spindle occupy recesses on the circular valve by which the latter may be rotated.

In order that the steam shall not escape past the valve spindle, the latter is provided with a coned portion which fits on the inside of the top cover, being pressed into it by the steam pressure.

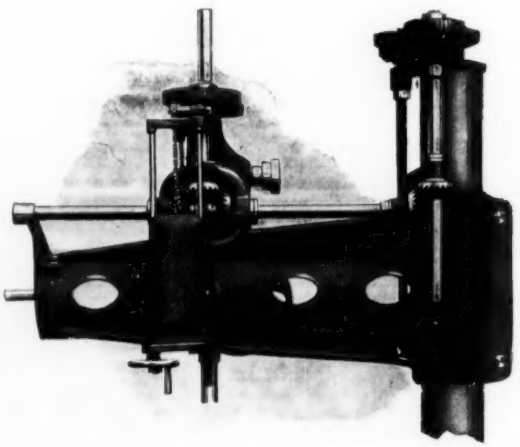
To prevent the cone from falling away from the recess when the valve is not under steam, a spring is provided between the coned part and the loose circular valve by which both are kept pressed against their respective seatings.

A spring also is provided on the spindle outside the valve between the casing and the wheel for turning the valve to help to keep the cone on the spindle on to its seating when the valve is not under steam. The valves, although designed chiefly for use with highly superheated steam, are equally suitable for other fluids at high temperatures and are suitable for working pressures up to 800 lbs. per sq. in. Provision for forced feed lubrication is made in the shape of an oil inlet. The makers are The Sheppee Motor Company, Thomas Street, York.

Improved Radial Drilling Machine.

A radial drilling machine embodying one or two features of interest has recently been introduced by Messrs. Midgley & Sutcliffe, Bradford, Yorks. It is illustrated in detail in the accompanying half-tones, which show a full front view and a back view of the arm and spindle head.

The bed is of strong box section, machined on the top



IMPROVED RADIAL DRILLING MACHINE: BACK VIEW OF ARM AND SPINDLE HEAD.

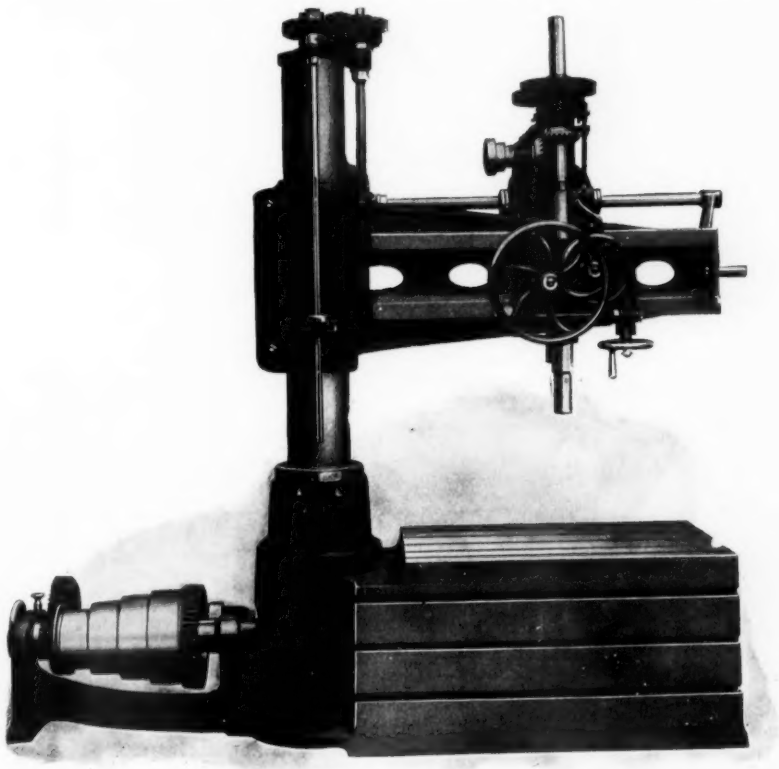
and front and all tee slots are planed out of the solid. The pillar is of strong section, revolving in the bed, and is ground to fit with double-bearing top and bottom. It can be gripped in any position. The arm is of special design and ribbed top and bottom to add to its strength. It can be gripped on the pillar, and is made to rise and fall by power.

The spindle head traverses along the arm by a machine-cut rack and pinion and also by a hand-wheel. The spindle is bored Morse taper and ground to fit a long cast-iron socket. It has hand and power feed arrangements, with complete tapping motion, clutch reverse, quick return, and balanced spindle. The rack on the socket is of steel, machine-cut, with machine-cut pinion. A hand-wheel is provided for quick adjustment of the spindle to and from its work. The drive is through cones and gearing.

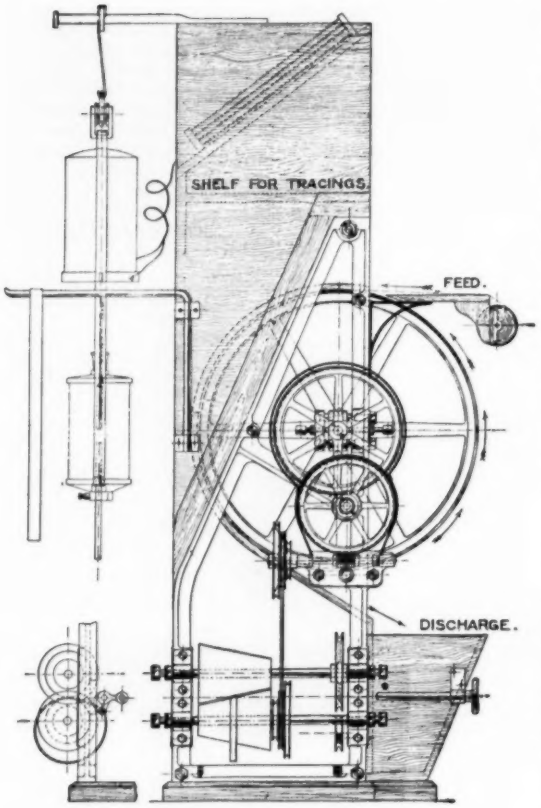
The machine is made in two sizes, one having a maximum radius to the centre of spindle of 4 ft. and the other of 4 ft. 6 in. Other leading particulars which are common to both machines are as follows: Rise and fall of arm on pillar, 1 ft. 10 in.; maximum distance spindle to bed, 2 ft. 8 in.; spindle to floor, 4 ft. 8 in.; speed of countershaft, 150 r.p.m.; size of base (smaller machine), 3 ft. 6 in. by 2 ft. 6 in.; larger machine 4 ft. by 2 ft. 6 in.

A New Continuous Copying Machine.

Of the electrical copiers which have for some time past been in vogue for the pre-



IMPROVED RADIAL DRILLING MACHINE.



NEW CONTINUOUS COPYING MACHINE.

paration of blue printed copies from tracings or original drawings, the vertical type has been most in evidence. Several advantages, however, are claimed for the new type of apparatus under notice of particular importance where a large output is required, in that the machine is capable of continuous work with the expenditure of very little time for adjustments. Further there is no liability of lateral or vertical creeping.

As will be seen from the illustration the machine consists of a drum 44 in. by 24 in., which is motor driven, through suitable gearing, in a direction away from the operator and towards the lamp. The tracing and printing paper are fed together on to this drum which, in revolving, presses them against a curved glass plate which extends for practically the whole length of the machine. The pressure between the drum and the glass can be varied and to this the prevention of creeping is due. Light is provided by three arc lamps suspended in a line level with the horizontal axis of the drum and a few inches from it. After printing the tracing and print are deposited in a hopper at the base of the machine as shown. A shelf for storing tracings until required is provided at the top of the machine, protection being afforded from the lamp resistances by asbestos sheeting.

The machine is driven by a ½ h.p. shunt-wound motor running at 1,400 r.p.m. Speed variation is obtained by means of stepped pulleys and by the cone drive shown. The surfaces of the two cones are arranged a little way apart, and in the space so left is inserted a short endless leather belt, which also passes over a jockey pulley. The position of this belt relatively to the cones is determined by means of a handle, which extends to the front of the machine, and by turning which the belt can be moved in one way or the other. This combination allows of a considerable range of speed, varying from 4 ft. per minute for rapid paper and good bold tracings to

FIG. 1.

3 in. per minute for the most difficult class of work.

The illustration shows the machine as arranged for feeding from a continuous roll of ferro-prussiate paper, but it is preferable, we understand, to first cut the paper to the size of the tracings before feeding, in which

FIG. 2.

case it is stated that fifty prints per hour can be made. 200-volt lamps are used, and if the quantity of work calls for it the placing of two machines back to back saves considerable current in that the lamps serve both machines. The apparatus is manufactured by B. J. Hall & Co., 39, Victoria Street, S.W.

Temperature Indicators for Hardening Steel.

One of the best-known phenomena manifested by carbon steel is that, when hardened at a temperature just above its recalescence point, it acquires great toughness combined with hardness, the grain, as exhibited by fracture, being of

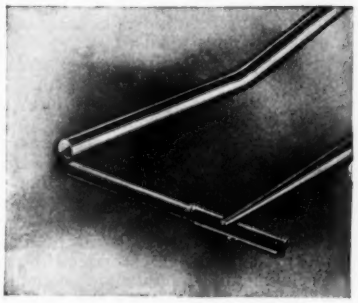


FIG. 3.

the finest. It is an interesting fact that at this temperature range, which extends from 720 to 740° C., carbon steel becomes non-magnetic, a circumstance which has been taken advantage of in the construction of an instrument for indicating precisely the temperature at which steel should be hardened. Overheating is mainly responsible for the warping, cracking, coarse grain, and brittleness in hardening tool steel, and any device by which the hardening point—that is when the change of dimensions is a minimum, and the steel therefore not liable to warp or crack—could be determined in a simple manner, would render valuable service in tool-making.

It has been customary for tool-makers to gauge temperature by the eye alone,

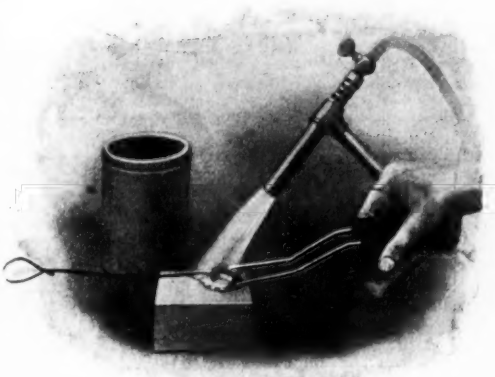


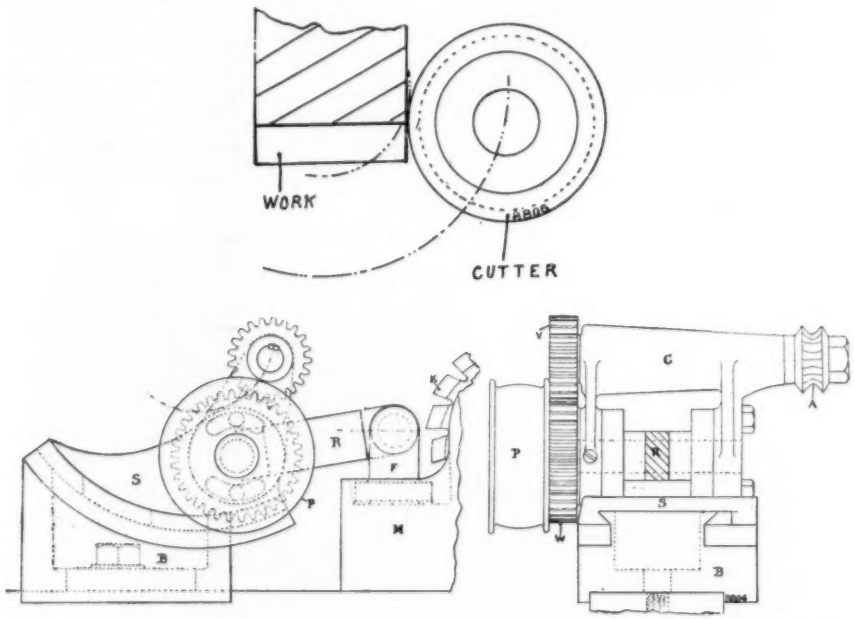
FIG. 4.

or, if pyrometers have been used, these have required the preparation of cooling curves for each sample of steel to be treated, and the use of pyrometers, somewhat delicate to handle, involves liability to error. The indicator about to be described, and which has recently been introduced by Messrs. Taylor, Taylor & Hobhouse, Limited, Leicester, requires no cooling curves to be taken, and has little or nothing that will get out of order. As will be seen from Fig. 1, the gauge consists of a permanent magnet, shaped conveniently for holding in the hand, its poles being prolonged by rods of special metal, which remain magnetic at temperatures higher than the hardening temperatures of carbon steels.

A small object is held upon the fingers of the gauge above a vessel of clean brine as in Fig. 2. On the object being heated by a blow-pipe flame, directed from above, when the correct temperature is reached it will automatically slide off the gauge into the brine and be quenched.

Fig. 3 shows the method of holding a tap or other piece which requires hardening, at one end only. It is placed under the fingers with the end to be hardened under the pointed finger. This end of the tool is heated evenly, and when the correct temperature is reached it drops from the pointed finger, and remains hanging vertically on the other finger ready for quenching. Pieces which are difficult to heat evenly in a blow-pipe, such as small milling cutters, are heated on a hearth as in Fig. 4, and the gauge applied to the piece being heated. It will be attracted by the gauge until it reaches the hardening temperature.

We are assured that, so accurate is the gauge, that unless the steel be instantly transferred to the quenching bath the loss of heat during the interval will prevent the object being fully hardened. It is unnecessary to use oil or warm water to reduce risk of cracking, brine being the liquid recommended, and many cutting tools, it is stated, may be advantageously used without subsequent tempering. The gauge illustrated is for light tools having a section not exceeding $\frac{3}{8}$ in. square; for larger objects the indicator is applied to a muffle furnace, and adapted to ring a bell when the steel reaches the critical temperature.



A RAPID GEAR-TOOTH ROUNDING DEVICE (FIGS. 1 AND 2).

(See page 230.)

Machine for Grinding Petrol Motor Cylinders.—A short time ago, I was employed by a firm of motor manufacturers who had a large order running for 30 h.p. four-cylinder engines. We were suddenly called upon to give larger deliveries, which we found our plant was quite equal to, with the exception of grinding out the cylinders. These cylinders were not of the twin type, but cast separately, and were about 4 in. bore and 4½ in. stroke.

Our existing facilities for grinding these cylinders consisted of a Landis universal grinder with internal grinding attachment, and as this was already overtaxed, we decided to construct a machine ourselves. Fig. 1 * shows the general arrangement of this machine. Fig. 2 an end elevation, with the feed driving pulley *I* removed.

A is an old capstan lathe bed, planed up, and *B* is the headstock. We rebored the bearing bushes, and put in a new spindle of larger diameter, and substituted a 2-cone pulley of wider proportions than the old 3-cone type; *C* is the traversing carriage, which carries the grinding spindle, the bearings of which are shown in section in Fig. 7. *D* is the cross slide, which is made to fit on the lathe bed; *E* is the ordinary screwed stud for taking the end thrust of the main spindle, shown with the two lock nuts removed; *F* is the feed box, bolted on to the side of the bed, also shown in detail in Figs. 3 to 6. This contains some novel points, and gives an instantaneous reverse, so important when grinding up to shoulders, &c. *G* is a lug cast on *F*; *H* is a spur pinion, which drives the feed screw *l* through the gears *J* and *i*. The pinion *H* is keyed on the hollow sleeved end of the bevel pinion *M*; *Q*, *Q* are two lock nuts for preventing end play; *I* is the feed driving pulley keyed on the shaft *K*, which passes through *M* and carries the sliding clutch *L*; *MI* is the reversing pinion secured by a pin and nut *O* and drives the pinion *N*, which is secured by the nut *P*. *M* and *N* have both clutch faces milled across front boss, and *N* supports the end of the shaft *K*, being bored out to receive it. *R* is a small bracket cast on the end of *F* for supporting the ¾ in. round steel sliding trip rod *S*, which carries two adjustable trip dogs *T* and *U*, each having a coil spring on the front as shown in Fig. 3; *r* two small brackets, cast on *D*, for carrying the trip rod *S*; *V* is a forked steel trip lever, shown in Fig. 5; *W* is a handle for starting and stopping the feed; *X* two setscrews for operating the clutch *L*; *Y* is a small hole for a peg for locking the feed to keep it from accidentally getting set in motion; *Z* is the pivot peg for *V* to rock on; *a* is a small bracket which carries the securing peg *Y* and also the knife-edged spring plunger *b*, also shown in Fig. 6; *e* is the screw for the cross feed of the grinding head; *f* is the driving pulley secured by the sunk grub screw *g*, as shown in Fig. 7; *h* shows the end of the bearing tapped out to receive a bronze bush, which takes the end thrust of the grinding spindle by adjusting it up to the collar on the end, as in Fig. 7; *m* are two brackets for carrying the feed screw *l*; *n* is the handle for feeding by hand or returning the wheel clear from the work; *p* is a knurled nut, which tightens *l* on *J* when the machine is at work. When this is slackened it allows of a free wheel arrangement with *J*, so that the feed can be operated by hand without throwing driving belt off or throwing the lever *V* in the neutral position by just slacking the nut *p*. This is a feature much appreciated by the operator.

When the machine is in operation the two adjustable dogs *T* and *U* are set to the length of stroke required and the feed started by pulling the handle *W*. As soon as either *T* or *U* comes in contact with *V* it commences to push the latter over until the hard steel knife edge, shown at Fig. 6, pushes the hard steel plunger *b* down to the position indicated. As soon as that happens the combined strength of the springs, of the dog in action, and at the bottom of the spring plunger *b*, force *V* over instantaneously and carry the sliding clutch *L* in the opposite direction, and thus engage with the clutch on the pinion, which reverses the feed instantly. The pinions *M* and *N* being constantly revolving in opposite directions, the end of the trip rod *S* clears the gear *i*, and the distance between the bracket *R* and the lever *V* is sufficiently long to allow of the machine having a working stroke of 15 in. stroke, which was quite long enough for all our requirements.

The above machine was constructed and at work inside three weeks, and although is not intended to be used for external grinding, it has quite exceeded our expectations for both speed and accuracy in cylinder grinding, a cylinder which formerly took 2½ hours to grind is now completed in 1¼ hours, and the same standard of accuracy maintained.

("J. GREEN.")

* See page 240.

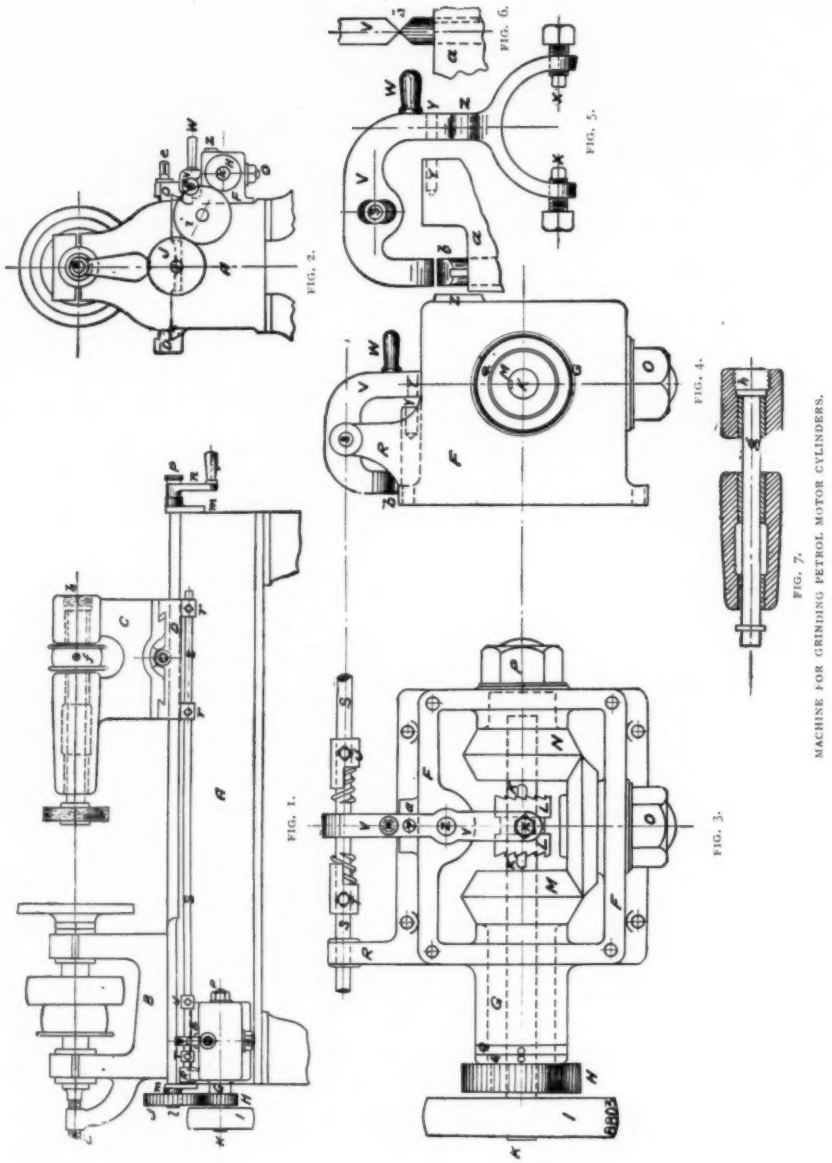


FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

FIG. 7.

MACHINE FOR GRINDING PETROL MOTOR CYLINDERS.

In this section is presented every month a list of the more important articles appearing in the Engineering Press and of the leading papers read before the various engineering institutions. Full names, addresses, and published prices of the publications indexed are printed each half-year in the volume index.

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Highway bridge over the Kansas River at Fort Riley, Kansas (*continued*). *Engineering Record*, *18th July*, 1908.

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Coal Bunkers of Reinforced Concrete. *Tramway and Railway World*, *July*, 1908.

Economy in Ferro-Concrete Design. By O. Faber. *Engineering*, *7th August*, 1908.

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Steam Turbine Construction, XIII. By T. Franklin. *Mechanical World*, *31st July*, 1908.

Hydraulics and Compressed Air.

Notes on Centrifugal Pumps, XIII., XIV. *Mechanical World*, *17th* and *31st July*, 1908.

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Tools and Equipment in Structural Shops. By G. P. Thomas. *Proceedings Engineers' Society, Western Pennsylvania*, *July*, 1908.

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A Machine for Handling Coke in Storage. *Engineering News*, *16th July*, 1908.

The Mechanical Engineering of Collieries (*continued*). By T. C. Futers. *Colliery Guardian*, *17th*, *24th*, *31st July*, and *7th August*, 1908.

The Belt Conveyer (*continued*). *Mechanical World*, *31s July*, 1908.

Gear Cutting Machinery, VII. *Machinery*, *July*, 1908.

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Cam Applications. Mechanisms employed in connection with Cams. By G. W. Armstrong. *Machinery*, *July*, 1908.

Some Interesting Features Concerning Gyroscopes. *Electrical World, New York*, *18th July*, 1908.

XUM

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An Abt Rack Locomotive for the Transandine Railroad. *Railway Gazette*, *24th July*, 1908.

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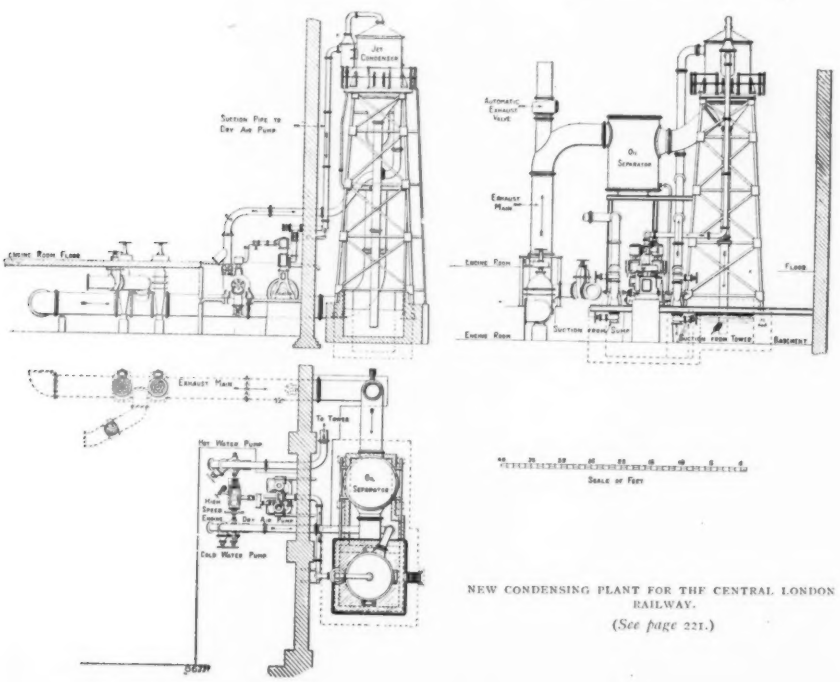

NEW CONDENSING PLANT FOR THE CENTRAL LONDON RAILWAY.

(*See page* 221.)

MANUFACTURERS' NOTES.

MESSRS. SOUPER & CALLAGHAN, engineers and agents, of 46, Grosvenor Chambers, Deansgate, Manchester, have formed a partnership for the purpose of carrying on business as buying and selling agents for all classes of machinery and engineering materials and supplies.—J. PARKINSON & SON, Shipley, announce that they have purchased the patent rights, plant, stock and entire interest in Taylor's "Instanter" vise, and that its manufacture, sale and control will in future be carried on by them, along with the manufacture and sale of their "Perfect" and "Handy" vises and other specialities. Mr. Charles Taylor has been appointed sole agent for the sale of "Instanter" vises for the Birmingham district.—THE UNITED STATES METALLIC PACKING CO., LTD., have changed the address of their London office from 17, Victoria Street, to 110, Fenchurch Street, E.C., telephone 2010, telegrams "Zircons."—MESSRS. SAMUELSON & CO., LTD., Banbury, intimate that they have terminated their exclusive arrangement with Messrs. Briddon & Fowler for the supply of milling machinery to them, and that they are now in a position to supply such machinery direct. We may remind readers that Messrs. Samuelson have been building this class of machinery since the year 1881, and that a very large number of machines of their manufacture have been at work for many years past in a number of the leading mills in this country and abroad.

TRADE LITERATURE.

WEBSTER & BENNETT, LTD., Coventry. Section A catalogue of boring and turning mills.—JOHN SPENCER, LTD., Wednesbury. Catalogue of iron and steel tubes and fittings.—MANSFIELD & SONS, LTD., Derby Square, Liverpool. Illustrated booklet descriptive of the firm's oil-gas apparatus.—INTERNATIONAL TIME RECORDING CO., 151, City Road, E.C. Inaccurate cost taking in most cases is due to the failure to properly distribute the overhead or non-productive charges, therefore the booklet just published by the company should be appreciated by manufacturers, works managers, cost clerks, and all interested in prime cost. It gives a simple and accurate method whereby the overhead burden is accurately distributed under any and all circumstances. It also, by various examples, shows where the majority of methods fail in use though perfect in theory.—GENT & CO., LTD., Leicester. Catalogue of water level indicators and alarms.—ALFRED HERBERT, LTD., Coventry. Ninth edition of Section J catalogue dealing with the firm's hexagon turret lathes. The principal recent improvement is the great increase in the amount of belt power delivered to the machine to take advantage of the possibilities of a roller steady tool. Recent tests have proved it possible to reduce the 2 in. diameter bar mild steel to ¾ in. diameter at one cut, with a feed of 11 in. per min., which means the removal of 7¾ lbs. of metal in one minute. The catalogue goes very fully into the description of the various parts of the machine, but most of them have been noticed previously in our columns.—SELIG, SONNENTHAL & CO., 85, Queen Victoria Street, S.W. 1908 catalogue of the "Selson" machine tools, specially designed for high speeds and heavy cuts, comprising shaping machines, radial drills, sliding, surfacing and screw-cutting lathes, and rapid reduction lathes.—FARNLEY IRON CO., LTD., Leeds. Illustrated booklet descriptive of the manufacture of the firm's specialty, and containing a list of sizes and weights of bar iron, angles, tees.—BEANLAND, PERKIN & CO., Leeds. Sectional catalogue H.S. of hack saw machines and blades.—RIMINGTON BROS., Carlisle. Two booklets dealing with power transmission, containing a description of the firm's specialties, such as shafting, couplings, hangers, blocks, lubricators, belts, &c. Also a list of appliances for positive lubrication.—VAUGHAN & SON, LTD., Manchester. A handsome illustrated catalogue of overhead travelling cranes.—CAMBRIDGE SCIENTIFIC INSTRUMENT CO., LTD., Cambridge. List No. 52 of physical instruments other than electrical instruments and thermometers. Also list No. 53 of galvanometers, Duddell thermo-galvanometers, magnetic standard, Grassot fluxmeter, &c. Also leaflet No. 54 of the Cambridge extensometer.—S. A. DANIELL & CO., LTD., Birmingham. List of screw stocks, dies and taps, screwing machines, tube cutters and wrenches, and general tools.—BOULTON & PAUL, LTD., Norwich. List of export buildings specially designed for tropical countries.—JAMES ARCHDALE & CO., LTD., Birmingham. Supplementary catalogue of lathes, illustrating a series of high-speed lathes from 6 in. to 14 in. centres, embodying all the latest labour-saving devices.—JAMES BALDWIN & CO., Keighley. Catalogue of stop valves and boiler mountings.

Dinner at the Mining Exhibition, Olympia.

An interesting function marked the close of the recent Mining Exhibition, at Olympia, in the shape of an exhibitors' dinner, presided over by Mr. Frank A. Hopkinson, of Messrs. J. Hopkinson & Co., Ltd., Huddersfield. Among the guests were: Messrs. H. G. Montgomery, M.P., and Hugh C. Montgomery, the organisers of the exhibition; and Mr. A. Gibb Maitland, State Geologist of Western Australia, representing officially Western Australia at the Franco-British Exhibition. The toasts were: "The Mining Industry," proposed by Mr. Mavor, and responded to by Mr. A. Gibb Maitland; "Mr. H. G. Montgomery," proposed by Mr. Charles Erith, of The Erith Engineering Co.; "The Technical Press," proposed by Mr. G. B. Woodruff, and responded to by Mr. C. H. Luke, of THE ENGINEERING REVIEW; and "The Chair," proposed by Mr. C. A. M. Buckley, of Ackroyd and Buckley, of Leeds.

A slight discussion followed, initiated by Mr. Mavor, as to advisability of regulating the intervals at which future exhibitions of the kind should be held.

On the following morning, Mr. C. H. Luke, of THE ENGINEERING REVIEW, was presented by Mr. A. L. Underwood, on behalf of a number of the exhibitors, with a handsome clock "in recognition of his services in promoting good-will and harmony."

SEVENTH WORKSHOP PRACTICE COMPETITION.

Readers are reminded that all articles for this competition, the particulars of which appeared in the July issue, should be addressed to the Editor of THE ENGINEERING REVIEW, 104, High Holborn, London, W.C., and marked on the outside, "Competition," and be received not later than September 5th.

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